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(Revised January 25, 1996)

## LOWER AQUIFER INVESTIGATION SOW AND SOPs

AMERICAN CHEMICAL SERVICE INC.  
NPL SITE  
GRIFFITH, INDIANA

PREPARED FOR:  
ACS RD/RA EXECUTIVE COMMITTEE

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**SCOPE OF WORK**  
**LOWER AQUIFER INVESTIGATION**  
(Vertical Profiling and Well and Piezometer Installation)  
Revised: January 25, 1996  
**American Chemical Service Inc.**  
**Griffith, Indiana**

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**SAMPLING METHODOLOGY**

**4.1.2 Lower Aquifer Investigation**

This phase of the investigation includes conducting the following activities at select locations ~~goals of the Lower Aquifer investigation are to:~~

- Determine the stratigraphy of the Lower Aquifer
- Determine the horizontal and vertical extent of VOC impacts in the vicinity of MW-9 in the Lower Aquifer groundwater contamination
- Determine if VOCs have reached the downgradient point of compliance from the site and if so, determine their vertical concentration profile in the Lower Aquifer
- Determine the vertical gradients in the Lower Aquifer
- Determine if dense, non-aqueous liquids (DNAPLs) are present in the Lower Aquifer

The investigation designed for the Lower Aquifer Investigation includes: collecting continuous core samples of lower aquifer matrix material, vertical profiling for target volatile organic compounds (VOCs) to collect groundwater at ten-foot intervals across the lower aquifer, installing nested monitoring wells and piezometers in the lower aquifer and sampling them, sampling production wells at the ACS facility, and monitoring lower aquifer water levels for approximately 30 days ~~an extended period.~~

The samples from the vertical profiling will be field analyzed for a target list of VOCs. VOCs were generally found to be an indicator of groundwater contamination at this site and VOCs are the most mobile constituents. The strong correlation between VOCs and site contaminants was documented in the Remedial Investigation (RI) Report. The target list of VOCs is: benzene, ethylbenzene, toluene, xylene, chlorobenzene, 1,2-dichloroethene, and 1,1-dichloroethane. These were the most frequently detected VOCs in groundwater samples collected from the Upper Aquifer (i.e., greater than four detections out of 24 samples)(see Table 7-2 of the ACS Baseline Risk Assessment Report.)

The general procedures for each of the investigation tasks are described below. Specific Operating Procedures are included as an attachment to provide sampling and analysis details.

Borings will be made in six areas surrounding the ACS facility (Figure 4-4a). These are labeled, clockwise from the west side of the ACS facility: MW9, MW10, MW8, MW7, MW28, and M4. Continuous core sampling of the lower aquifer will be conducted at each of the locations. Vertical profiling (groundwater sampling at ten foot depth intervals) will be conducted at the four downgradient locations.

The objective is to collect continuous core samples across the lower aquifer at all locations, and groundwater samples every ten feet to the base of the lower aquifer at the four downgradient locations. A well record for ACS production well IW3 indicates that the bedrock below the lower aquifer is at a depth of approximately 120 to 130 feet below ground surface. Ground surface at this location is approximately 640 feet above mean sea level (amsl). Therefore, the bedrock should be encountered at the approximate elevation of 510 feet amsl. The top of the clay confining layer that separates the upper and lower aquifers is generally encountered at about 620 feet amsl, and is 5 to 15 feet thick. Therefore, it is anticipated that coring and vertical profiling will be conducted across approximately 100 feet of saturated lower aquifer.

The general investigation sequence at the downgradient locations will be to set casings for each borehole to be made, conduct aquifer coring and vertical profiling in the first boring, and set a piezometer near the bottom of the lower aquifer. Then, one or more boreholes will be drilled without collecting core samples to install the other wells or piezometers. Upon completion, each location will contain three screened devices (monitoring wells or piezometers), one near the base of the lower aquifer, one approximately half way down in the lower aquifer, and one at the top of the lower aquifer. One or two of the devices will be two-inch stainless steel monitoring wells, with ten-foot stainless steel screens. The other one or two devices will be PVC piezometers with five-foot screens. The activities to be conducted at each location are summarized in Table 1 and described below.

### Setting Casing

The upper aquifer is contaminated with organic compounds, among others. In addition, there is a strong downward gradient across the confining layer. Therefore, 8 inch casings will be set with a hollow stem auger rig for each boring to isolate the lower aquifer from the upper aquifer. At each boring location, an eight inch casing will be sealed with cement bentonite grout into the top 12 inches of the clay confining layer. Table 2 lists the calculated depth to the top of the confining layer at each location, based on the boring information from the RI. These data will be used where the data is definitive, to determine the depth necessary to drill to place the casing. Where data is uncertain or unavailable, split spoon samples will be collected on 2.5 foot centers from 10 to 15 feet below ground surface, until the clay confining layer is encountered. The attached SOP provides the details regarding setting of casings. Text below specifies the method to select casing depth for each location.

### Continuous Core Collection

Based on the assumption that bentonite mud would not be used during the drilling process, Sonic drilling was selected. Sonic drilling will be as an appropriate method for making the

boreholes to collect representative stratigraphic samples of the aquifer material, collect groundwater samples at multiple depths in the lower aquifer while drilling, and installing monitoring wells and piezometers.

At the first boring at each of the six locations, continuous core samples will be collected starting at the base of the casing, and continuing to the base of the lower aquifer, which will be indicated by the presence of bedrock. Continuous cores will be collected in ten foot lengths, extruded into core boxes, evaluated and stored on site. The attached SOP provides the details regarding field screening the core, photographing it, logging it, and storing it in a core box. Handling of borehole cuttings and purge water are discussed at the end of this SOW.

It can be anticipated that aquifer material will "blow in" to the casing after core samples are removed at some depths in the lower aquifer (heaving sands). Efforts will be made to minimize the problem without using water or drilling fluids. An advantage of sonic drilling is that the length of the core barrel can be extended to 20 and 30 feet if necessary. Then the increased core barrel length can be used to remove "blow in" and still collect the sample. For example, if ten feet of aquifer has blown into the casing at a certain depth interval, a 20 foot core barrel can be used to collect both the blow-in and the next sampling interval. In this case, the first ten feet extruded would represent the new aquifer interval and so it would be collected. The second ten feet of sediment would represent blow-in and be managed as excess cuttings.

#### **Vertical Profiling of the Lower Aquifer**

The objective of determining the presence of DNAPLs and to screen for the vertical and horizontal extent of VOCs in the lower aquifer will be accomplished by vertical profiling at the four downgradient locations, MW9, MW10, MW8, and M4. These locations are distal from the known source areas. Vertical profiling will be conducted by collecting a groundwater sample from each ten-foot interval across the lower aquifer.

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After each ten-foot core run is extracted from the borehole, a power punch (Hydropunch type device) will be used to insert a sampling point into the zone that was just cored. If inspection of the core indicates the potential for contamination, the power punch will be used to place the sampling screen at the depth of concern. If there is not evidence of contamination, the power punch will place the sampling screen in the center of the ten foot core zone. The attached SOP provides the details for collecting the groundwater sample.

#### **Piezometer and Monitoring Well Installation**

Following completion of the continuous coring to the base of the aquifer, a piezometer will be placed in near the bottom of the lower aquifer (Assuming that there is no indication of contamination at the bottom of the aquifer). The preliminary indication is that the lower aquifer will end at bedrock at an elevation of approximately 510 feet amsl. Therefore, unless otherwise indicated in the field, the base of the piezometer screen will be placed at an approximate elevation of 510 feet amsl. (If a layer of clay is found to overlay the bedrock,

the screen will be placed above the clay depth.) The attached SOP provides details regarding installation of piezometers.

Monitoring wells will be placed at five of the investigation locations (MW9, MW10, MW8, MW28, and M4). The attached SOP provides details regarding the installation of the 2-inch diameter stainless steel wells with ten foot screens that will be installed. At locations MW10 and MW8, if the vertical profiling indicates that VOC contamination exists, the monitoring well will be situated so that the well screen intersects the zone of highest concentration. At MW-9, the well will be set at the bottom of the contaminated zone to define the vertical extent of contamination. If more than one zone of VOC contamination is indicated, separated by more than ten feet, a field decision will be made whether to install an additional well.

If VOC contamination is not indicated by the vertical profiling, the well will be screened at an elevation to correspond with other piezometers and wells in the lower aquifer. The monitoring wells currently situated in the upper zone of the lower aquifer are screened at an elevation of approximately 600 feet amsl. The bottom zone piezometers will be screened at an approximate elevation of 510 feet amsl. If there is no indication of contamination, monitoring wells and piezometers in the middle zone of the aquifer will be screened so that the base of the screen is located at an approximate elevation of 555 feet amsl (or the middle of the aquifer if the bedrock is deeper or shallower than anticipated). The attached SOP provides details regarding the installation of piezometers and monitoring wells.

While the same general procedures will be followed at each investigation location, there will also be differences. The following lists the current monitoring status at each location and lists the activities that will be conducted.

**MW9** Existing well MW9 is screened in the upper zone of the aquifer west of the ACS facility. Two casings will be set to isolate the upper aquifer at this location. One casing will be set for the vertical profiling and a piezometer screened near the base of the lower aquifer and the second, for a monitoring well screened in the middle zone of the lower aquifer. The intent of the middle zone well is to determine the vertical extent of contamination in the lower aquifer. On the basis of the vertical profiling, it this well will be placed with its screen just below the zone of contaminated groundwater, indicated by the existing well. Future sampling will provide an indication if the existing contamination spreads deeper.

As indicated in Table 2, the top of the confining layer will be encountered approximately 16.5 feet below the ground surface at this location. Therefore the borings will be advanced to approximately 17.5 feet to set the casings. Boring with continuous core sampling will be conducted through one of the casings, from the confining layer to the base of the lower aquifer. Vertical profiling samples will be collected for each ten-foot interval of the lower aquifer. Samples will be analyzed in the field gas chromatograph (GC) for the Lower Aquifer Compound

List parameters. The attached SOP provides the details of the field GC. Table 1 of the attached SOP provides a listing of the Aquifer Compound List parameters.

A 2-inch diameter piezometer will be placed at the bottom of the first borehole. A second boring will be drilled to place a 2-inch diameter stainless steel monitoring well at the depth determined by the vertical profiling, to be the depth of the vertical extent of contamination, or if no contamination is found, at the 555 foot elevation representative of the middle zone of the lower aquifer.

**MW10** Existing well MW10 is screened in the upper zone of the aquifer northwest of the ACS facility. Two casings will be set to isolate the upper aquifer at this location. One casing will be set for the vertical profiling and a piezometer screened near the base of the lower aquifer and the second casing will be set for a monitoring well screened in the middle zone of the lower aquifer. As indicated in Table 2, the top of the confining layer will be encountered approximately 14 feet below the ground surface at this location. Therefore the borings will be advanced to approximately 15 feet to set the casings.

Boring with continuous core sampling will be conducted through one of the casings, from the confining layer to the base of the lower aquifer. Vertical profiling samples will be collected for each ten-foot interval of the lower aquifer. Samples will be analyzed in the field GC for the Lower Aquifer Compound List parameters.

A 1-inch diameter piezometer will be placed at the bottom of the first borehole. A second boring will be drilled to place a 2-inch diameter stainless steel monitoring well at the depth determined by the vertical profiling the depth of the highest concentration of contamination, or if no contamination is found, at the 555 foot elevation representative of the middle zone of the lower aquifer.

**MW8** Existing well, MW8 is screened in the upper zone of the aquifer north of the ACS facility. Two casings will be set to isolate the upper aquifer at this location. One for the vertical profiling and a piezometer screened near the base of the lower aquifer and the second for a monitoring well screened in the middle zone of the lower aquifer. As indicated in Table 2, the top of the confining layer will be encountered approximately 21 feet below the ground surface at this location. Therefore the borings will be advanced to approximately 22 feet to set the casings.

Boring with continuous core sampling will be conducted through one of the casings, from the confining layer to the base of the lower aquifer. Vertical profiling samples will be collected for each ten-foot interval of the lower aquifer. Samples will be analyzed in the field GC for the Lower Aquifer Compound List parameters.

A 1-inch diameter piezometer will be placed at the bottom of the first borehole. A second boring will be drilled to place a 2-inch diameter stainless steel monitoring well at the depth determined by the vertical profiling the depth of the highest concentration of contamination, or if no contamination is found, at the 555 foot elevation representative of the middle zone of the lower aquifer.

**MW7** Existing well, MW7 is screened in the upper zone of the aquifer east of the ACS facility. Two casings will be set to isolate the upper aquifer at this location. One casing will be set for the continuous core sampling and the placement of a bottom zone piezometer and the second casing will be set for the middle aquifer zone. As indicated in Table 2, the top of the confining layer will be encountered approximately 20.5 feet below the ground surface at this location. Therefore the borings will be advanced to approximately 21.5 feet to set the casings.

Boring with continuous core sampling will be conducted through one of the casings, from the confining layer to the base of the lower aquifer. A 2-inch diameter piezometer will be placed at the bottom of the first borehole. A second boring will be drilled to place a 2-inch diameter piezometer with the base of the screen at the 555 foot elevation representative of the middle zone of the lower aquifer

**MW28** There are no lower aquifer wells at the present time in the area indicated by MW28 (Figure 4-4a). Monitoring wells MW17 and MW18 are in the general vicinity. Three casings will be set to isolate the upper aquifer at this location. Table 2 indicates that the top of the confining layer will be encountered approximately 20 feet below the ground surface at this location. However since a boring has not been made into the lower aquifer at this location, split spooning will be conducted on 2.5 foot centers in the first casing borehole, starting at a depth of 15 feet below ground surface, and continuing until the clay confining layer is encountered. The total depth for the boreholes to set the casings will be established by the split spoon sampling. The casing will be set 12 inches into the confining clay layer.

Boring with continuous core sampling will be conducted through the first casing from the confining layer to the base of the lower aquifer. A 2-inch diameter piezometer will be placed at the 510 elevation representative of the bottom zone of the lower aquifer. Another boring will be drilled through the second casing to place a 2-inch diameter piezometer with the base of the screen at the 555 foot elevation representative of the middle zone of the lower aquifer. ~~If reasonable by field conditions and acceptable to the U.S. EPA, two piezometers may be installed in a single borehole.~~ The third casing will be used to set a 2-inch diameter stainless steel well with ten foot screen at an elevation to represent the upper zone of the aquifer. If field screening of the continuous core indicates no contamination, the screen will be placed at an elevation of approximately 600 feet

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amsl. If contamination is indicated, the screen will be placed to intersect the aquifer zone of potential contamination.

- M4** Comment 22 in December 8, 1995 EPA letter raised the issue of abandoning existing Griffith Landfill Well, M-4D. A review of the monitoring data indicated that this well is not causing cross-contamination of the lower aquifer; therefore it does not need to be abandoned and it may be used to represent the upper portion of the lower aquifer at this location. (Data supplied by the City of Griffith for M4D is included in attachment F). #13

All drilling in this location will be postponed until after the barrier wall alignment borings have been completed to provide evidence of the appropriate location for the borings. When that determination has been made, two casings will be set to isolate the lower aquifer from the upper aquifer at this location. The depth to the top of the confining layer is uncertain at this location. Therefore, split spoon sampling will be conducted on 2.5 foot centers in the first casing borehole, starting at a depth of 15 feet below ground surface, and continuing until the clay confining layer is encountered. The casing will be set 12 inches into the confining clay layer.

Boring with continuous core sampling will be conducted through the first surface casing from the confining layer to the base of the lower aquifer. Vertical profiling samples will be collected for each ten-foot interval of the lower aquifer. Samples will be analyzed with the field GC for the Lower Aquifer Compound List parameters.

A 2-inch diameter piezometer will be placed at the bottom of the first borehole. A second boring will be drilled to place a 2-inch diameter stainless steel monitoring well at the depth determined by the vertical profiling the depth of the highest concentration of contamination, or if no contamination is found, at the 555 foot elevation representative of the middle zone of the lower aquifer.

#### **Surveying New Well Locations and Reference Elevations**

After the lower aquifer monitoring wells and piezometers (and the upper aquifer wells proposed in the "Tracer Investigation" report) have been completed, a surveyor will establish the horizontal location and vertical location in terms of the existing site datum. Horizontal locations will be determined to the nearest 1.0 foot; vertical reference elevations will be established with a 0.01 foot accuracy.

#### **Continuous Monitoring of Water Levels in the Lower Aquifer**

To provide an extended record of variability of water levels in the upper and lower aquifer at the site, three locations (MW7, MW9, and P-8) will be instrumented with transducers and a data logger during the lower aquifer investigation. The data logger will be set to record water levels in these three measurement points for approximately 30 days during the lower aquifer investigation. The data loggers will be set to record water levels every 30 minutes.



Data loggers will be checked each day and the depth to water will be measured and recorded in the field book. If a data logger is found to be at variance from the measured depth by more than 0.1 foot, the data logger will corrected and re-set after downloading the data. In any case, the ~~and~~ data will be downloaded every seven to ten days. The data will be used to develop a plot of groundwater elevation versus time in each the upper and lower aquifer. The attached SOP provides the details for setting up the transducers and running the data loggers.

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#### **ACS Production Well Evaluation and Sampling Well Sampling**

Four active production wells and two abandoned production wells have been identified at the ACS facility (See Figure 2-29). Wells IW1 through IW4 are the active wells. Each consists of a four inch casing and operates on a daily basis. These four wells will be sampled following the SOP for Active Production Well Sampling in the attached SOP. Samples will be submitted to an approved off-site laboratory for analysis of TCL VOCs. Quality Assurance samples will include a duplicate sample, and a trip blank, a matrix spike, and matrix spike duplicate sample (MS/MSD).

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The abandoned production wells, IW5 and IW6 will be inspected and field evaluated in accordance with the attached SOP. The inspection and investigation for each well will include:

- Examining the surrounding area and the physical condition of the casing
- Sounding the well to determine total well depth and the depth to water
- Determining if there is any non-aqueous liquid in the well
- Reclosing the well

Based on the findings, recommendations will be made regarding further investigation or sampling, and possible abandonment.

#### **Well Abandonment**

Per IDEM comments at the September 1995 meeting, no wells will be abandoned at this time.

#### **Handling of Investigation Derived Wastes**

The drilling and the collection of cores will generate a significant volume of cuttings from each borehole. In addition, purging prior to sampling for the vertical profiling will generate excess extracted groundwater. Several drum will be staged near each lower aquifer investigation location. One will be identified as the drum for solid cuttings and one will be identified for purge water. Other drums will be maintained for additional waste, if one or both of the drums becomes filled. The filled drums will be marked to indicate the source, and staged in the investigation derived waste area. The drummed purge water and soil cuttings will be maintained on site until the site remedy is functioning. ~~At each boring location, the continuous core samples will be evaluated by PID and the groundwater will be analyzed by the on-site GC from ten foot intervals. If the PID indicates levels above background or if the vertical profiling GC analysis indicates the presence of volatile~~

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~~waste drum storage area for treatment when the site remedial system is operating. If the PID scan and the GC analysis of the water samples indicates no contamination, the cuttings will be spread on the ground and the purge water will be poured out on the ground. The emptied drums will be re-used at the next investigation location.~~

### **Attachments**

- Table 1.      Summary of Lower Aquifer Sampling Activities and Well and Piezometer Installations.  
Table 2.      Elevations and Depths of Confining Layer  
Figure 2-29.   Production Well Location Map  
Figure 4-4a.   Proposed Lower Aquifer Investigation.

PJV/

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Revised by PJV, 1-25-96

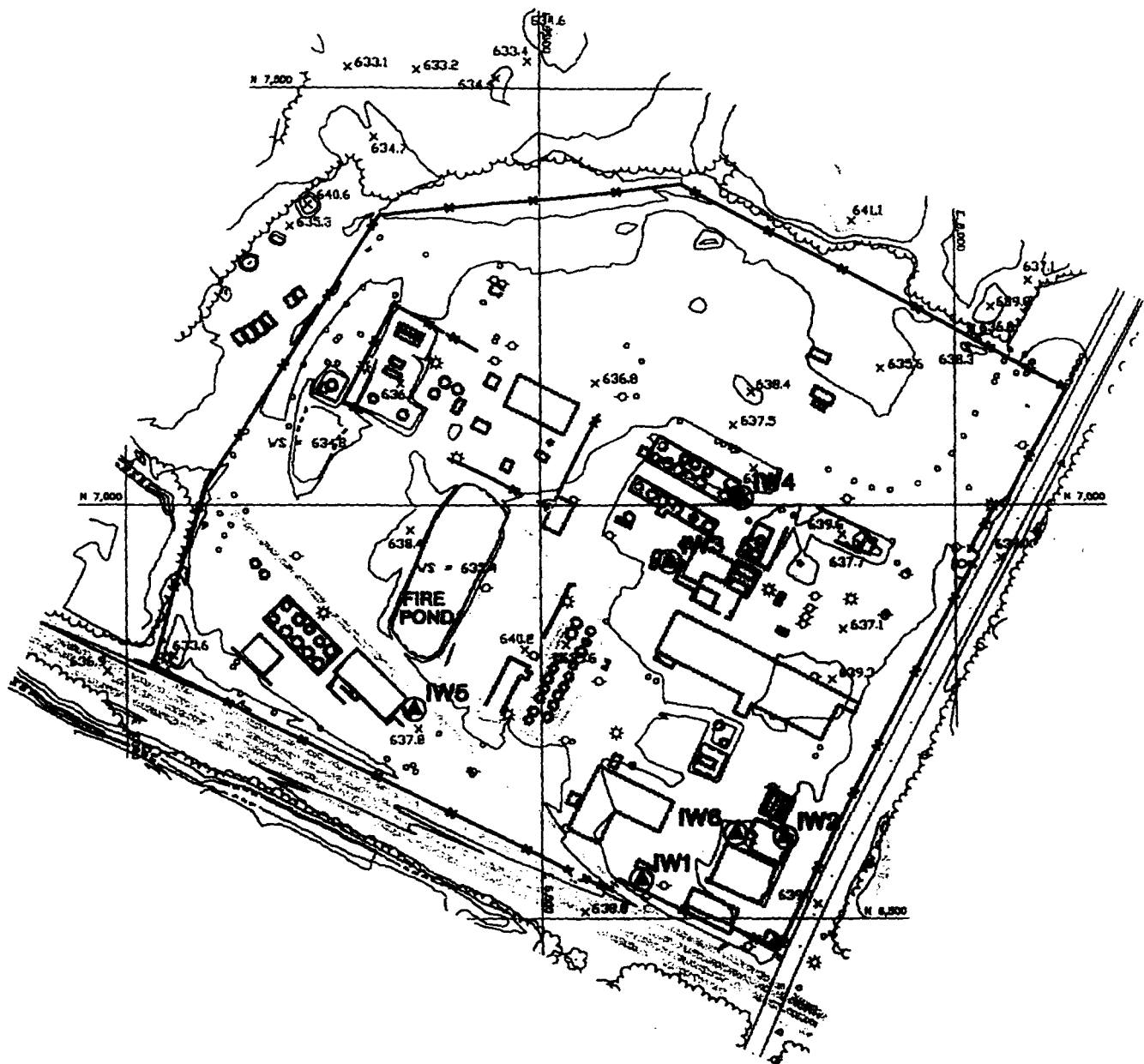
4077.0080

Table 1. Summary of Lower Aquifer Sampling Activities and Well and Piezometer Installations.

	Sampling		Wells and Piezometers		
	Continuous Core Sampling	Vertical Profiling	Upper Zone	Middle Zone	Lower Zone
MW9	Yes	Yes	MW9 (existing)	New well	2" piezometer
MW10	Yes	Yes	MW10 (existing)	New well	1" piezometer
MW8	Yes	Yes	MW8 (existing)	New well	1" piezometer
MW7	Yes	No	MW7 (existing)	2" piezometer	2" piezometer
MW28	Yes	No	New well	2" piezometer	2" piezometer
M4	Yes	Yes	M4 (existing)	New well	2" piezometer

Table 2. Elevations and Depths of Confining Layer

Well Locations	Elevation (feet amsl)			Depth (feet) to Confining Layer
	Ground Surface	Top of Confining Layer	Bottom of Confining Layer	
MW9	635.9	619.4	610.7	16.5
MW10	633	619.2	612.8	13.8
MW8	638.2	617	605.7	21.2
MW7	638.7	618.2	600.2	20.5
MW-18 MW28	645.4	625.4	unknown	20
M4	634	620	unknown	14

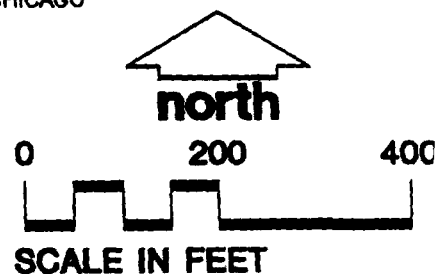


### LEGEND

- IW1 INDUSTRIAL WATER WELL LOCATION AND NUMBER
- FENCE LINE
- RAILROAD TRACK
- TOPOGRAPHIC CONTOUR

### NOTES

1. BASE MAP DEVELOPED FROM AN AERIAL SURVEY MAP OF THE SITE FLOWN ON MARCH 8, 1994 BY GEONEX CHICAGO AERIAL SURVEY, INC.
2. VERTICAL DATUM IS U.S.G.S. DATUM. CONTOUR INTERVAL IS 2ft.
3. WELLS NUMBER 5 AND 6 ARE INACTIVE.



**FIGURE 2-2**

Developed By PMS-BAP Drawn By TMS,TPB,LCL  
 Approved By [Signature] Date 8/17/95  
 Reference \_\_\_\_\_  
 Revisions Δ IW5 AND IW6 RELOCATED. 08-13-95

### PRODUCTION WELL LOCATION MAP

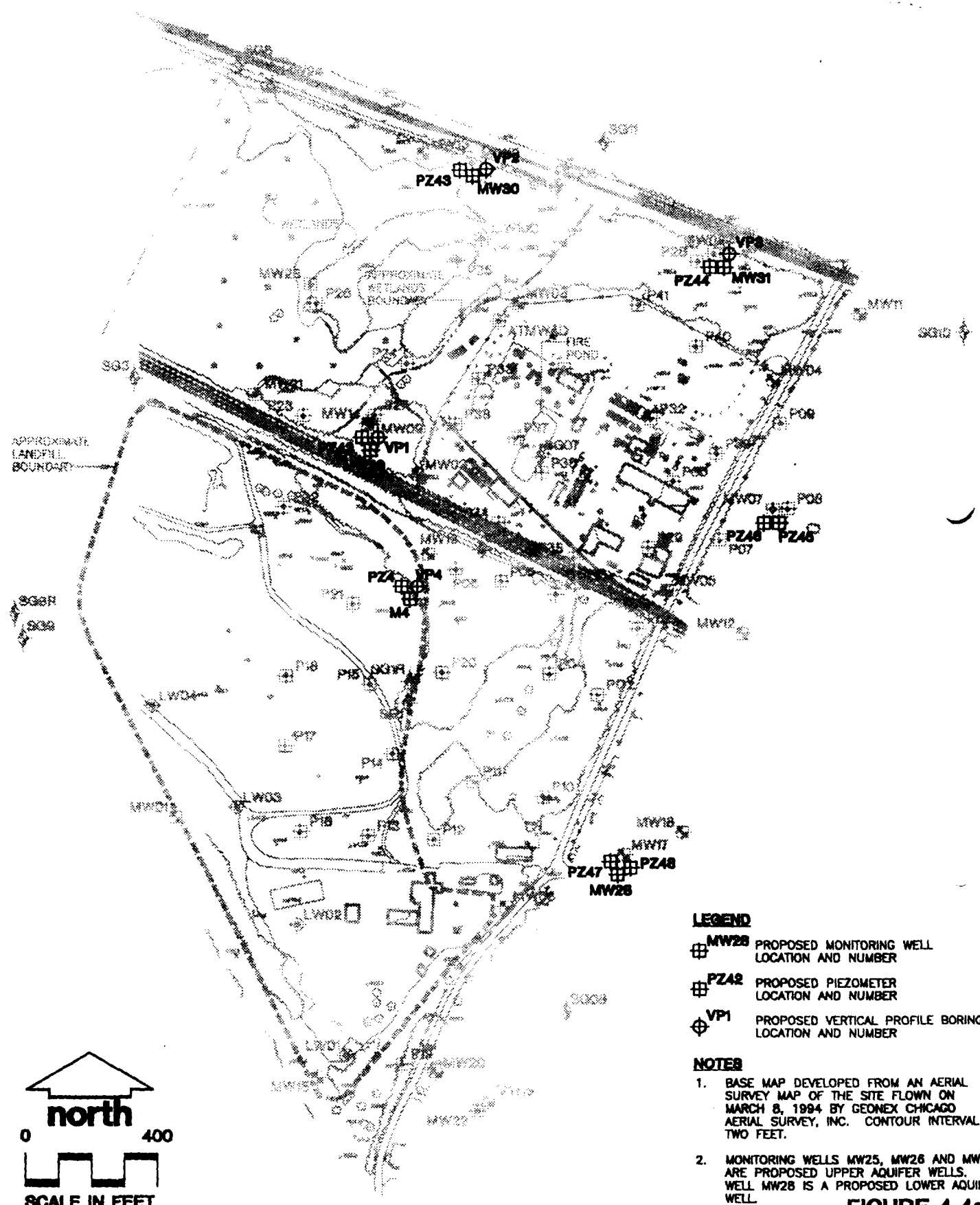
PRE-DESIGN WORK PLAN  
 AMERICAN CHEMICAL SERVICE, INC.  
 NPL SITE  
 GRIFFITH, INDIANA

Drawing Number  
 4077.0030 **A4/**

**MONTGOMERY  
 WATSON**



Management Review  
 Other  
 Manager  
 PI  
 Lead Professional  
 TROL  
 Graphics Standards  
 The information shown on this drawing is a summary of the information provided to the firm by the client. It is not to be used without the written approval of Montgomery Watson.



**LEGEND**

- MW25** PROPOSED MONITORING WELL LOCATION AND NUMBER
- PZ42** PROPOSED PIEZOMETER LOCATION AND NUMBER
- VP1** PROPOSED VERTICAL PROFILE BORING LOCATION AND NUMBER

**NOTES**

1. BASE MAP DEVELOPED FROM AN AERIAL SURVEY MAP OF THE SITE FLOWN ON MARCH 8, 1994 BY GEONEX CHICAGO AERIAL SURVEY, INC. CONTOUR INTERVAL TWO FEET.
2. MONITORING WELLS MW25, MW26 AND MW27 ARE PROPOSED UPPER AQUIFER WELLS. WELL MW26 IS A PROPOSED LOWER AQUIFER WELL.

**FIGURE 4-4a**

Developed By <b>DAP</b>	Drawn By <b>DLF</b>	<b>PROPOSED LOWER AQUIFER INVESTIGATION</b>  PRE-DESIGN WORK PLAN AMERICAN CHEMICAL SERVICE, INC. NPL SITE GRIFFITH, INDIANA	Drawing Number <b>4077.0030 A68</b>
Approved By <b>[Signature]</b>	Date <b>12/22/95</b>		<b>MONTGOMERY WATSON</b> 
Reference			
Revisions			

# **SPECIFIC OPERATING PROCEDURES**

## **LOWER AQUIFER INVESTIGATION**

Revised: January 25, 1996

**American Chemical Service Inc.  
Griffith, Indiana**

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### **SONIC DRILLING SAMPLING PROTOCOL**

**Scope and Application:** This method is applicable to drilling unconsolidated formations for soil and groundwater sampling and well installation.

**Method:** The Sonic Drilling Method uses a sonic drill rig that has a specially designed hydraulically powered drill head or oscillator which generates adjustable high frequency vibrational forces. The sonic head is attached directly to the core barrel, drill pipe, or outer casing, sending the high frequency vibrations down through the drill steel to the face of the drill bit. This method uses simultaneous high frequency vibrational and low speed rotational motion coupled with down-pressure to advance the cutting edge of a circular drill string.

#### **I. PRE-FIELD CHECKLIST**

- A. Health and Safety Plan with related instruments
- B. Underground Utility Check: 5 to 7 day advance notice required
- C. Off-Site Access agreements completed
- D. Statement of Work detailing sample types, sample intervals, drilling and sampling methods
- E. Field boring logs (Montgomery Watson Standard)
- F. Daily Drilling Summary
- G. Unified Soil Classification System summary
- H. Decon solutions, brushes, buckets
- I. Soil jars (Laboratory Grade and Driller's Grade)
- J. Jar labels

- K. Small Iced Coolers
- L. Driller contacted and informed
  - 1. Health and Safety Plan
  - 2. Utility check
  - 3. Statement of Work/Sampling Plan
  - 4. Disposal of purge water
- M. 150 ft tape measure
- N. Pocket penetrometer
- O. Soil knife/spatula
- P. Utility Knife
- Q. Well Construction Forms
- R. Well Development Forms
- S. Core Boxes

## II. FIELD CHECKLIST

- A. Check for unmarked or uncleared utilities, drive around, walk around
- B. Check for overhead wires
- C. Drill rig access
- D. Health and Safety Briefing
- E. Borehole location correctly staked and labeled
- F. Steam clean drill rods, casing, bits, core samplers, hand tools, drill rig
- G. Count number of drill rods to determine the number used during drilling and therefore, the total depth drilled
- H. Count number of various size casing pieces to determine the number used during drilling and therefore, the total depth of casing in the ground
- I. Measure length of core sampler
- J. Confirm the correct well construction materials are present



K. Soil jars prepared

### III. SETTING CASING (Using Hollow Stem Augers)

- A. This method is applicable for sealing off an upper aquifer from a lower aquifer while drilling through a confining layer. The upper portion of the borehole down to the confining layer may be drilled using 12-in I.D. hollow stem augers to set an 8 in casing.
- B. Advance the borehole to the predetermined depth of the confining layer.
- C. Confining layer depth will be determined as described in the Scope of Work.
- D. The casing should be advanced and seated approximately 1 ft into the confining layer.
- E. Grout casing in place using cement/bentonite slurry, from the base of the bore hole up, as the 12-in hollow stem auger is slowly pulled back.
- F. Vertical profiling and piezometer and well installations may continue through the casing 24 hours after grouting the casing in place.

### IV. AQUIFER MATRIX SAMPLING

- A. Core through the confining layer inside the 8 in casing.
- B. Collect the first 10 ft interval lower aquifer matrix sample
  - 1. Retract filled core barrel with drill rods
  - 2. Extrude collected sample into 5 ft plastic sleeves
  - 3. Lay filled sleeve in core box
  - 4. Slit plastic sleeve with knife
  - 5. Headspace PID will be made from several (one to three) samples from each ten-foot core recovered. Samples will be selected on the basis of the appearance of contamination (i.e., dark coloring) or if a fine grained layer is identified that would represent a lower permeability unit (i.e., clay or clayey silt).
    - a. Place selected aquifer material sample in glass jar.

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- b. Cover the jar with aluminum foil and seal with screw-type cap.
- c. After the jar has rested at room temperature for a period of 5-10 minutes, shake the jar, then make the headspace reading by inserting the PID probe through the aluminum foil cover.
- 6. Photograph core sample with label identifying core sample number
- 7. Place core sample in core box. Label top and bottom of core run.
- 8. Log geologic description
- C. Collect water sample (see Section V: Vertical Profiling - Groundwater Sampling)
- D. Drive casing to base of recently cored 10-ft section
- E. Repeat steps B through D until base of lower aquifer is reached
- F. Set Piezometer or well as appropriate (see Section VI - Installation of Wells and Piezometers)
- G. Collect three samples and submit to geotechnical laboratory for grain-size analysis.
  - 1. Each borehole will have three screened devices (monitoring wells or piezometers). Select one sample to represent each screened section of the aquifer from each borehole.
  - 2. Collect each sample into a 4 oz sample jar. Label jar with core boring location and depth of sample.
  - 3. Submit to geotechnical laboratory for grain-size analysis (copy of ASTM D-422-63 is included with this document)

V. VERTICAL PROFILING - GROUNDWATER SAMPLING

- A. After removing core barrel with soil sample, insert power punch to cored interval for sampling.
- B. Pull back water-tight power punch casing, exposing 1.75-in x 4-ft. screen.
- C. Purge water with down-hole pump capable of pumping 200-300 ml/minute.
  - 1. Place pump 1-ft above top of screen (approximately 5-ft from bottom of power punch)

2. Purge one-and-a-half screen volumes of water for initial purge (approximately 0.75 gallons for 1.75-in x 4-ft. screen).
  3. After initial purge, monitor temperature, conductivity, turbidity, and pH by inserting instrument probes into by-pass stream or bucket filled with continuous flow from pump, as available
- D. When temperature, conductivity, turbidity, and pH stabilize, collect water samples for analysis of VOCs by field GC. The quantities will be assumed stable, when they do not vary more than 10 percent between readings.
1. Affix an adhesive label to the sample container prior to sample collection. Condensation may form on containers after filling which would make it difficult to adhere labels.
  2. Remove plastic cap and Teflon coated septum being careful not to contact potential contaminants. If vial and/or cap appears to be defective, discard and use a new vial. The vial should be opened for a minimum amount of time. Two (2) 40-ml. vials must be collected for each sample.
  3. Carefully fill vial with continuous low flow from the Grundfos pump with aqueous sample until meniscus (mound of water) forms on top. Avoid agitating sample as this may cause a loss volatiles. Because samples will be analyzed within 7 days of collection, no 1:1 HCL sample preservation is required. All samples should be kept at 4°C until analysis.
  4. Carefully replace (Teflon side down) the cap on meniscus. This will force a small amount of water off the top. Check the vial for air bubbles by inverting vial and tapping the side of the vial gently. Bubbles will rise to the top if present. If bubbles are present, remove cap and top off vial to create a new meniscus. If bubbles are present, ~~after three attempts discard vial and start with new one. Analysis of samples with air bubbles may not give representative results.~~
  5. After successful collection of each groundwater sample, immediately take vials to field laboratory for analysis in a small iced cooler. The field laboratory will maintain an iced cooler for temporary sample storage until sample is ready to be analyzed.
- E. On-site analysis will be conducted with field Gas Chromatograph (GC) instrument, as described in the following Field GC, Purgeable Volatile Analysis Protocol, starting on page 14.

## VI. INSTALLATION OF WELLS AND PIEZOMETERS

The installation procedure is the same for installing one and two inch diameter PVC piezometers and two inch diameter stainless steel monitoring wells. Monitoring wells are constructed of 2 inch stainless steel material, and fitted with ten-foot screens. Piezometers are constructed of 1 or 2 inch PVC material, and fitted with five-foot screens.

The elevation to place the screen will be either pre-determined or will have been selected on the basis of the vertical profiling results (See SOW). Each monitoring well or piezometer will be installed through the sonic casing that was used to maintain the hole after continuous coring.

### A. Before Well Installation

1. Inspect screen and riser pipe inside and out for cleanliness, defects, gouges, cracks: reject any failed pieces.
2. Accurately measure length of screen piece including blank sections.
3. Measure total length of slotted interval
4. Accurately measure length of each riser piece.
5. Count the number of riser pieces to confirm accurate total length of well.
6. Inspect filter pack material: proper gradation, popper material, contaminant free, sufficient quantity.
7. Inspect bentonite: 100 percent Wyoming bentonite with no additives, proper size, sufficient quantity for placing well seal.

### B. During Well Installation

Retract outer casing to the depth established to place the screen. Fill the abandoned core with bentonite slurry pumped through the center of the core barrel casing, from the base of the bore hole up, while raising the core barrel casing to screening interval.

1. Determine depth of well placement as total length of assembled well string minus height of well string to above ground surface.
2. Riser pieces should have water tight joints: either neoprene gaskets or Teflon tape. Do not use glue or solvent cement.
3. Accurately determine total well depth.

- a. Measure length of well riser pipe piece cut off from the total length of well string.
  - b. Total well string length minus length of cut off piece equals total well depth (TD) measured from top of casing (TOC).
  - c. The well top should stick up a minimum of 24 inches above the ground surface.
4. Install a temporary well cap to prevent any materials from falling into the well. Lower well string down into the casing to the predetermined depth.
5. Filter pack construction
  - a. Introduce a well graded sand in a controlled manner: slowly add filter sand. Slowly retract the casing surrounding the screen.
  - b. Filter pack will extend from 6 inches below the well bottom to 2 feet above the top of the well screen.
  - c. Periodically use tape measure to check for bridging and to show height of filter pack in comparison to the well screen.
6. Bentonite Seal:
  - a. Use bentonite chips or pellets no larger than 3/8 inch in diameter when placing seal through water.
  - b. Place minimum two feet of bentonite seal above the filter pack.
  - c. Place 6 inches of fine sand on top of the bentonite seal
  - d. Record the type, size, and volume of sealant placed.
7. Annular Space Seal. All permanent monitoring wells will have an annular space seal which extends from the top of the filter pack seal to the bottom of the ground surface seal and will have a minimum two foot length.
  - a. For water table wells with the water table at 7 feet or less below ground surface, use granular bentonite only; place the bentonite in 2 foot lifts, hydrating each lift
  - b. Use thick bentonite slurry or bentonite-cement grout for placing annular space seal greater than 50 feet deep. Caution: Use of Portland Cement may result in grout contamination of the well (high pH) if improper seals or improper recipes are used. Consult with the project hydrogeologist.
    - (1) Bentonite slurry recipe: 2 lb. of granular bentonite per gallon of water, or as thick as the driller can pump it; Rule of thumb: Thick slurry tends to shear in the mud tub rather than flow.
    - (2) Bentonite-cement grout recipe: It is important to closely follow this recipe; deviation from this recipe may result in grout contamination of the well. Mix 6 1/2 gallons of water per 94 lb.

bag of Portland Type I cement then add 3 to 5 lb. bentonite powder. This will yield about 1 1/2 times the volume of water used. Carefully measure the amount of water: Too much water causes persistent pH problems in the well (grout contamination).

- (3) Tremie pump sealant from the bottom up using a side discharge tremie pipe. Pump the sealant until it flows full strength, undiluted, up and out through the top of the hole.
  - (4) Allow a 12-hour period between installing slurry or grout and installing the protective casing to allow for settlement and curing. If a 12-hour waiting period is impractical, the slurry or grout should be bailed out down to the water table. The annular space should then be filled using bentonite chips, pellets, or granules as described below.
  - (5) The top of the seal should not be higher than 5 ft. below ground surface - remove excess grout by bailing it out before it sets up.
  - (6) Avoid using bentonite slurry as annular space sealant in the unsaturated zone. Bentonite slurry will flow into the unsaturated zone leaving a void space in the unsaturated annular space. Pump slurry to the top of the borehole, let it settle for 12 hours, then use "c" or "d" below.
- c. Use bentonite chips no larger than 3/8 in. diameter or bentonite pellets when there is less than 30 ft. of standing water in the borehole and the depth to the bottom of the annular space seal is less than 50 ft. (except when the depth to water table is less than 7 ft. use granular bentonite). Place pellets or chips slowly in a controlled manner. Check for bridging. Hydrate in the unsaturated zone
  - d. Use granular bentonite.
    - (1) When there is no standing water in the borehole and the placement depth is less than 25 ft.
    - (2) The depth to the water table is less than 7 ft. below ground surface.
  - e. Record type and volume of annular space seal.
8. Construct ground surface seal. Check for annular space seal settlement. If grout or slurry is used as the annual space seal, wait 24 hours after seal installation before installing the surface seal.

a. Stick up well protective pipe.

- (1) Measure the length of well protective pipe.
- (2) Subtract well stick up height to get embedment depth of well protective pipe.
- (3) If the well protective pipe embedment depth intersects the filter pack or filter pack seal, then shorten the length of the well protective pipe. The minimum embedment depth should not be less than the stick up height.
- (4) The ground surface seal will start at least 5 ft. below ground surface.
- (5) Place bentonite chips, pellets or granules up to 1 ft. below the well protective pipe embedment depth, then place 1 ft. of filter sand.
- (6) Set the well protective pipe onto the firm bed of filter sand.
- (7) Add granular bentonite around the outside of the protective pipe only and hydrate it to 2 ft. lifts to the surface.
- (8) Concrete ground surface seals in regions where the ground freezes are not recommended. Frost heave will jack the concrete seal and the well protective pipe out of the ground. If it is necessary to construct a concrete ground surface seal in regions affected by freezing ground, the concrete should be at least 4-ft. diameter, 8-in. thick, with reinforced mesh poured onto 4-in. of compacted road gravel. The concrete should not be poured onto fine grained soils not should it be in contact with bentonite. The concrete should be sloped radically away from the well casing. Concrete should not be in contact with the well casing. This may seem excessive, but anything less is very likely to be ruined by frost action.
- (9) Do not place bentonite between the protective pipe and the well casing.
- (10) If the monitoring well depth is such that both a minimum 2 ft. annular space seal and a minimum 5 ft. ground surface seal cannot both be placed, the ground surface seal may be shortened.
- (11) Record the depth to the bottom of the ground surface seal, also record the length and diameter of the well protective pipe.

- (12) The well protective pipe should stick up a minimum of 24 in. above the ground surface and should always extend above the top of the well.
- (13) The top of the well pipe must be within 4 in. of the top of the well protective pipe.
- (14) The well protective pipe should not extend into the annular space seal not into the filter pack.
- (15) The well protective pipe should be filled with filter sand to within 12 in. of the top of the well.
- (16) A weep hole may be drilled into the well protective pipe; a small vent hole should be cut or drilled into the well can.

#### C. After well installation

- 1. Check for settlement of the ground surface seal; top off as necessary.
- 2. Label the protective casing with the well number.
- 3. Stick up wells: label the well cap inside and out with the well number.
- 4. Lubricate the well lock.
  - a. Do not use WD-40 nor penetrating oils.
  - b. Remove the lock away from the well and lubricate it with liquid graphite.
  - c. Wipe off excess lubricant, allow the lock to "dry", then return it to the well.
- 5. Stick up wells in high traffic areas: consider placing bumper posts around the well.
  - a. Wood or steel, set in concrete or bentonite.
  - b. At least 8 ft. long with 4 ft. stick up.
  - c. Posts may be painted or flagged.
  - d. Do not paint the well protective casing.
- 6. Clean up the area: pick up trash, do not burn; pick up cuttings; use a broom, rake, or hose down the area.



## ACTIVE PRODUCTION WELL EVALUATION AND SAMPLING

**Scope and Application:** To provide guidelines for collection of production well samples.

### **Reagents and Apparatus:**

1. Assorted tools
2. 50' hose (5/8" and 1/2" adapters)
3. 5 gallon bucket
4. Sample containers, sample labels
5. Chain-of-Custody forms
6. Cooler with ice

### **Procedure:**

1. Schedule Sampling with Tom Froman, ACS.
2. Label all sample containers prior to collection
3. Locate the untreated, cold water source. If possible, the sample should be collected directly off the pressure tank or from a tap between the pump and the pressure tank. Verify that the sample has not passed through any type of treatment system (water softener, iron filter, hot water heater, etc.). Record the exact location the sample was taken.
4. The well/pressure tank system should be purged by allowing the water to run for ten minutes and until the pump has cycled at least once. After the water has run for ten minutes and the pump has cycled, measure and record the temperature at five minute intervals. When two consecutive temperature measurements agree within 1.0 degree C, it can be assumed that the running water represents new formation water and a sample can be collected for analysis. ~~for at least 10 minutes or until the pump cycles on and off several times.~~ Connect a hose to the faucet or collect purged water in bucket for disposal in a nearby drain. Remove the hose prior to sample collection. #18
5. Fill appropriate containers for analyses of VOCs. Consult Sample Collection and Preservation SOP (SCP).
6. Clean up sampling area if necessary.

## ABANDONED PRODUCTION WELL EVALUATION

**Scope and Application:** To evaluate condition of abandoned production wells, and obtain an accurate measurement of the depth to bottom of well and water level.

### **Reagents and Apparatus:**

1. Weighted Tape (0.01 foot graduations)
2. Electronic water level indicator (assorted models)
3. Photoionization Detector (PID) - Hnu or Thermo Environmental
4. Oil Interface Probe(optional)
5. Water level recording form (field observation sheet or field log book)
6. Squirt bottle of D.I. water
7. Tri-Sodium Phosphate (TSP) or Alconox cleaning substance.

### **Procedures:**

1. Locate abandoned production well and carefully remove well cover if possible.
2. Allow short time (1 to 3 minutes) for water in well and air to equilibrate (Well may be under some pressure during initial removal of cover).
3. Screen breathing zone above well for the presence of volatile organic compounds (VOCs) with a PID.
4. Inspect well casing near the surface for possible damage (i.e., cracks, potential conduits to the lower aquifer). Record observations of well condition into the field log book.
5. Lower oil interface probe into well and record depth to oil/solvent (continuous beeping) and depth to water (oscillating beep) to the nearest 0.01 ft, utilizing the highest elevation of well casing as a measuring point. Record thickness of product (difference between level of product minus water level) and both product and water levels in field log book. Measure depth to product and water two times to verify. Note, if field observations during initial taping of the well indicates presence of product which may damage oil interface probe, the measurements will not be taken, and observations will be documented into the field log book.

6. If floating product is detected in the well, do not attempt to determine the total depth of the well, by lowering the probe to the bottom, since this could carry contaminants deeper into the aquifer.
7. If the oil interface probe does not indicate the presence of NAPLs, lower the oil interface probe slowly into well until the bottom of well is reached. This will be determined by an absence of tension in the tape as it is being lowered, or the initiating of tension in the tape as it is being raised back to the surface.
8. Measure and record depth of well to the highest point of the well casing near the surface. Record measurement in field log book to the nearest 0.01 ft. Take two readings to verify.
9. Reinstall well cover onto the production well.
10. Rinse off water level indicator or oil interface probe with distilled water. If product is present, wash water level indicator or oil interface probe with a trisodium phosphate and distilled water wash, followed by a distilled water rinse.

# FIELD GC - PURGEABLE VOLATILES ANALYSIS PROTOCOL

## Scope and Application

This method covers the determination of volatile organic compounds in a variety of aqueous matrices in a mobile field laboratory using a gas chromatograph interfaced with a purge & trap. Refer to Table 1 for ACS Lower Aquifer specific compounds and reported detection limits (RDLs). The mobile laboratory will be operated by Montgomery Watson laboratory personnel experienced in fixed and mobile lab operations.

## Method Summary

In a mobile laboratory setting, samples are analyzed using a purge & trap interfaced to a GC equipped with a capillary column and photoionization (PID) and electrolytic conductivity detectors (ELCD). This method provides qualitative identification and estimated quantification of VOCs.

## Method Reference

"Test Methods for Evaluating Solid Waste", SW-846, July 1992, Methods 5030A and 8021 (modified).

## Reporting Limits

Refer to the Lower Aquifer Compound List (Table 1) for field screening compounds and reporting limits at the ACS site. RDLs may also be affected by high levels of organic compounds, matrix related problems or other interference's.

## Optimum Range

Up to 100 times the reporting limit for each matrix group. The optimum range may also be affected by specific compounds, the individual program needs, or project reporting limit requirements.

## Reagents and Apparatus (Apparatus can be substituted with equivalents.)

1. Open screw cap 40 mL vial (Pierce #13075 or equivalent).
2. Septum: Teflon-faced silicone (Pierce #12722 or equivalent).
3. Purge & trap device: SRI - interfaced to a 8610 GC
4. Trap (primary): Tenax GR (6 x 1/8 in.)
5. Trap (secondary): Carbosieve (6 x 1/8 in.)
6. Purge tubes: 25 mL disposable culture tubes (16x125 mm)
7. Gas chromatograph: SRI 8610 equipped with PID and ELCD detectors in series, megabore capillary column adapters, makeup gas.
8. Column (primary): 15 m x 0.53 mm I.D., MXT-1 metal capillary column, 5 um film depth.  
Alternate column: J&W 30 M DB624 or equivalent
9. Glass Syringes: 5 mL Leurlock tip, 1 mL Hamilton, 100 uL Hamilton, 10 uL Hamilton, and 25 uL Hamilton
10. Balance:  $\pm 0.0001$  g (Mettler AE200) (for lab use only)
11. Balance:  $\pm 0.1$  g (Ohaus LS200)

12. Reagent water - water which has been shown to be organic-free at the method reporting limits.
13. Methanol - B&J Brand Purge & Trap Grade
14. Beakers - assorted
15. Volumetric flasks - assorted
16. Pipettes - 5 and 10 mL volumetric
17. Mininert Valves - Leurlock
18. Helium - ultra high purity grade
19. Air- zero grade or breathing grade (for ELCD)
20. Standards (refer to reagent preparation section)

### **Standards Preparation**

1. **Stock Standard Solution:** Stock standards should be prepared prior to going into the field. Prepared stock standard solutions at 5,000 ug/mL may be purchased from a vendor. Alternatively, prepare a VOC standard containing the target compounds at 5000 ug/mL in methanol.
  - Add about 20 mL of methanol to a 25 mL volumetric flask. Allow the flask to stand unstoppered until the methanol on the neck of the flask has dried. Replace the stopper.
  - Tare the flask on the analytical balance.
  - Remove the stopper and, using a 100 uL syringe, add 0.125 g (correct for % purity) of the reference material to the flask. Make sure the drops fall directly into the methanol without contacting the neck of the flask. Replace the stopper.
  - Determine the mass of reference material added. Rinse the syringe with methanol, tare the flask, and add the next reference standard.
  - After the reference materials are added, fill to volume with methanol, cap, and invert to mix.
  - Transfer the final stock standard to a screwtop vial for storage.
2. **Secondary Standard Solutions:** Secondary standards should be prepared weekly and stored at 4°C. Prepare secondary solutions in methanol according to the following scheme:

<u>Standard</u>	<u>mLs</u>	<u>Final Volume</u>	<u>Concentration</u>
5000 ug/mL	1 mL	10 mL	500 ug/mL
500 ug/mL	1 mL	10 mL	50 ug/mL
50 ug/mL	2 mL	10 mL	10 ug/mL

(e.g., add 1 mL of the 5000 ug/mL standard to a 10 mL volumetric flask and fill to the line with methanol and cap. The resulting solution has a concentration of 500 ug/mL.)

3. **Working Calibration Standards:** Prepare calibration standards in DI water according to the following scheme:

<u>Standard</u>	<u>mLs</u>	<u>Final Volume</u>	<u>Concentration</u>
500 ug/mL	20 uL	200 mL	50 ug/L
50 ug/mL	40 uL	200 mL	10 ug/L
50 ug/mL	20 uL	200 mL	5 ug/L

Fill a 200 mL volumetric flask with reagent water to the mark. Directly inject the secondary standard into the water with an appropriate microliter syringe.

Invert the standard 3 times, discard the first 10 mL in the neck of the volumetric flask and transfer aliquots of the standard into a 40 mL VOC vials (no headspace) for storage.

4. **Surrogate Standard:** Surrogate stock standards may be purchased or prepared in advance. The stock standard contains the following two surrogates in methanol:

<u>Compound</u>	<u>Concentration</u>
a,a,a-Trifluorotoluene	2000 ug/mL in Methanol
1,4-Dichlorobutane	2000 ug/mL in Methanol

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**Surrogate Working Standard:** For the working surrogate solution, add 50 uL of the TFT stock surrogate solution, and 50 uL of the 1,4-DCBA stock surrogate solution to a 10 mL volumetric flask, and dilute to 10 mL with methanol. This is equal to a 10 ug/mL working surrogate solution. Add 5 uL of the surrogate solution (10 ug/mL) to each standard, sample and blank.

#### Notes

1. This method is intended for use only by an experienced GC operator in a mobile field laboratory.
2. Apparatus can be substituted with equivalents.
3. Gas chromatographic conditions may be changed to optimize the analysis, provided that performance is determined to be equivalent to that of initial demonstration of capabilities.

#### Procedure

- A. **Gas Chromatographic Conditions:** (Note: SRI rental GCs are configured by SRI for the chosen method prior to shipment. Refer to the SRI manual for specific GC and purge & trap conditions. Conditions vary depending on column choice. The following are provided as an example.)

**Column:** 30 m x 0.53 mm I.D., DB624 or equivalent

**Carrier Gas:** Helium  
5 mL/min

**Detectors (in series):**

1. Photo Ionization - 10.0 eV  
Sensitivity - Range 10  
Temperature - 230°C
2. Electrolytic Conductivity - SRI dry electrolytic conductivity detector  
Mode - Halogen  
Reactor temperature - 1100°C

**Oven:**

Initial - 35°C, Hold for 10 min  
Ramp - 4°C/min  
Final - 200°C

**Purge & Trap System:**

Trap: tenax/carboxeive 3000  
Purge Flow: 40 mL/min  
Purge Time: 5 minutes  
Dry Time: 3 minutes  
Desorb Preheat: 245°C  
Desorb: 6 minutes at 250°C  
Bake: 4 minutes at 260°C  
Transfer line: 100°C

**B. Calibration**

The instrument must be calibrated daily for all compounds of interest before samples are analyzed. Initial calibration standards must be run at three concentrations, followed by a method blank. The initial calibration must meet the criteria presented in the Quality Control section of this method prior to the analysis of samples. A continuing calibration standard must be run after every ten samples, and at the end of the day. The continuing calibration must meet the criteria presented in the Quality Control section of this method prior to the analysis of samples.

Follow the chart presented above for working calibration standards to prepare standards. Note that concentrations for specific compounds such as xylenes and ketones may vary.

**C. Loading Procedure:** (All standards, water samples, and the purge water for direct soil purging are loaded into purge tubes on the purge & trap in a similar manner.)

1. Fill a 5 mL luerlock syringe with sample or standard. To fill the syringe, remove the plunger from the barrel. Uncap the 40 mL VOC vial, and slowly pour the sample into the barrel, taking care to minimize sample volatilization. Fill the

barrel to the top, insert the plunger and adjust the volume. Add 5 uL of the surrogate solution (10 ug/mL) to the sample.

2. Load the sample onto the purge & trap.

If the purge & trap has a sample valve, use the following procedure:

- a) Luerlock the syringe filled with sample to a sample valve on the purge & trap.
- b) Open the sample valve.
- c) Inject the sample into the purge tube with a smooth, steady flow.
- d) Close the sample valve (free end away from line), and remove the syringe.

If the purge & trap does not have a sampling valve, use the following procedure:

- a) the sample must be transferred directly to the purge tube with a slow, smooth steady flow.
- b) Attach the purge tube to the purge & trap and hand-tighten the nut.

**D. Analysis of Water Samples:**

1. Load calibration standards from low concentration to high onto the instrument as noted in the loading procedure above. Start the GC program to purge the sample and begin the analysis.
2. Prepare a method blank by filling the 5 mL syringe with 5 mL reagent water. Add 5 uL of the surrogate solution (10 ug/mL) to the sample. Load onto the purge & trap and analyze. A method blank must be analyzed daily, or for every batch of 20 or fewer samples of a similar matrix, or whenever potential carryover problems are expected.
3. If all criteria is met for the initial calibration, samples can be loaded onto the instrument and analyzed.
4. Samples are prepared by filling the 5 mL syringe with 5 mL of sample. Add 5 uL of the surrogate solution (10 ug/mL) to the sample. Load onto the purge & trap and analyze.
5. After every batch of 10 or fewer samples of a similar matrix, a calibration check must be analyzed. Prepare the 10 ug/L check standard as outlined in the "Calibration" (Section B) section of this SOP.
6. If the sample response for any of the compounds is greater than the response of the highest calibration standard for any analyte, dilution is required. The level of the dilution should be such that the concentration of the analyte(s) is (are) approximately mid-range in the calibration.



## Quality Control

### 1. **Initial Calibration Criteria:**

- a) A minimum of 3 calibration levels must be included in the curve. One of these levels must be at the RDL.
- b) The correlation coefficient ( $r$ ) for the calibration curve must be  $\geq 0.995$  ( $r^2 \geq 0.990$ ).
- c) The y-intercept expressed as concentration must be  $< \text{RDL}$  for each analyte.

### 2. **Calibration Check Standard:** After every 10 or fewer samples of each matrix and at the beginning and end of the day, a check standard containing all the compounds in the calibration curve must be analyzed (at 10 ppb). All analytes should fall within $\pm 30\%$ of the concentration for the system to be considered in control. If this criteria is not met, determine whether the compound was detected in any of the bracketed samples. If so, run a standard at the RDL (5 ppb). If the 5 ppb standard is $\geq 50\%$ recovery for that analyte, then no qualification of data is necessary. If the 5 ppb standard is $< 50\%$ then the associated sample data compounds must be qualified. #20

### 3. **Method Blank:** A method blank must be analyzed at the beginning of every working day before any samples are analyzed and for every batch of 20 or fewer samples of a similar matrix. All compounds of interest must be less than the reporting limit. If any compounds are found in the blank above the reporting limit, corrective action must be taken to alleviate the contamination. Any samples analyzed with the problem blank must have the detected compounds flagged on the final report.

### 4. **Surrogate Recovery:** Working surrogates are added to each standard, blank, and sample to monitor the performance of the method. Surrogate recoveries are calculated as a percent using the area counts from the sample or blank divided by the area counts from the initial calibration 10 ug/L standard. If a surrogate recovery falls outside of the acceptable control limits of 50 to 150 percent, the sample should be reanalyzed. If the surrogate recovery from the repeat analysis falls outside of the control limits, flag the data as estimated due to matrix interference. If the surrogate recovery for a blank falls outside acceptable limits, the run must be halted and the problem corrected before additional samples may be run.

### 5. **Sample Results:** Sample results are not considered complete until bracketed by acceptable standards. Results should also be evaluated for blank contamination and surrogate recovery. Results should not be considered final until peer reviewed. Release of preliminary draft results prior to peer review is strongly discouraged. Users of preliminary draft results should be warned the data is not final and is subject to revision.

### Calculations

**Water Samples:** Prepare a linear regression curve for each compound using a calculator or spreadsheet and the formula:

$$y = xb + a$$

where

y = compound response

x = concentration in ug/L

b = slope

a = y-intercept

Therefore, the sample concentration would be:

$$x = ((y-a)/b) \times \text{dilution factor}$$

### Data Reporting

1. All notes, standard conditions, and results will be recorded in a bound notebook.
2. All data generated by field GC will be considered to be tentatively identified, with concentration being estimated.
3. All raw data and the bound notebook will be maintained in the Montgomery Watson project file for final review and archiving.

JRH/PJV  
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4077.0070  
GC SOP Revised: 1/25/96

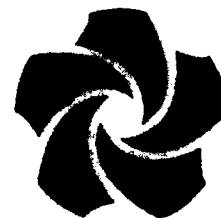
**TABLE 1**  
**Site Target Compound List, Retention Times, & Reporting Limits**  
**Field GC Purgeable Volatiles by Method 8021**  
**For Lower Aquifer, Vertical Profiling Samples**  
**American Chemical Services**  
**Griffith, Indiana**

<u>Compound List</u>	<u>Retention Times</u>		<u>RDL</u>
	<u>MTX-1</u> <u>(min)</u>	<u>DB-624</u> <u>(min)</u>	<u>Waters</u> <u>(ug/L)</u>
<b>ACS Site Target List</b>			
<i>Acetone</i>	9.0	10.6	20
1,1 Dichloroethene	10.3	10.0	5
trans 1,2 Dichloroethene	11.0	13.7	5
1,1 Dichloroethane	11.3	15.6	5
<i>2-Butanone (MEK)</i>	11.7	17.8	20
cis 1,2 Dichloroethene	12.0	17.6	5
1,2 Dichloroethane	13.3	20.3	5
1,1,1 Trichloroethane	13.5	19.0	5
Benzene	14.1	20.0	5
<i>Carbon tetrachloride</i>	13.8	19.3	5
Trichloroethene	15.9	21.7	5
<i>4-Methyl-2-pentanone (MIBK)</i>	17.8	24.5	10
<i>1,1,2 Trichloroethane</i>	18.3	25.8	5
Toluene	18.6	24.8	5
Tetrachloroethene	20.0	25.9	5
<i>Chlorobenzene</i>	20.8	27.9	5
Ethylbenzene	21.1	28.1	5
m+p Xylene	21.3	28.4	10
<i>Styrene</i>	21.5	29.3	5
o Xylene	21.8	29.2	5

**Notes:**

This table presents the ACS Site Target List to be analyzed using the Field GC Purgeable Volatiles SOP (Method 8021). Note that the Work Plan specifies Method 8010/8020; Method 8021 is a more current VOC method that specifies the use of purge & trap and capillary columns. Both primary and secondary columns retention times are included to allow for flexibility in the field. Retention times will vary depending on GC conditions.

The *italicized* compounds have been added so that the list includes all compounds detected during the RI at concentrations exceeding 100,000 ug/kg (100 ppm), or 1% of the ROD definition of soils classified as waste (i.e., soils with total VOC concentrations of 10,000 ppm).



# **BOART LONGYEAR COMPANY**

## **ENVIRONMENTAL DRILLING DIVISION**

### **SONIC DRILLING**

#### **Inquire at these locations:**

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Peoria, Arizona 85345 USA  
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**Boart Longyear Company  
Environmental Drilling Division**

**Sonic Drilling**

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## Sonic History

Research on rotary-vibratory (sonic) drilling techniques began in the late 1940's. The best-documented work in the U.S. was performed by the Drilling Research Institute (DRI). Russia also worked on developing sonic drilling prior to 1950. At a meeting in 1957 at the Moscow Drilling Institute, drilling rates of 3 to 20 times that of conventional methods were reported. The current state of development in Russia is unknown.

Supported by the petroleum industry, DRI started research and development in 1946 and terminated their efforts in 1958 when funding was discontinued. The goal of this effort was to speed up oil well drilling operations by adding vibrations to the rotary motion of the drill pipe and to enhance well development or rejuvenation.

In the early 1960's an inventor in the United States, supported by Shell Oil Company continued the research and development efforts. He developed a downhole device that used a series of eccentric weights driven by drilling fluid to generate vibration. He also developed a top-head, high horsepower vibrator to be used for pile driving and a smaller oscillator for driving smaller pilings, installing casing under roadways, and drilling seismic shot holes. This and other activity continued until the late 1960s, when Shell stopped funding the project. A British manufacturer continued development efforts until 1983 using the inventors prototypes. Several patents were applied for and received. All have since expired.

From 1976 to 1983 when activity was suspended, the British company was successful in developing a smaller sonic drill rig. They built approximately 10 drill rigs and 15 sonic heads. These heads are some of the basic units used on the drill rigs in operation today.

North Star Drilling Company (North Star) became a division of Boart Longyear in 1994. North Star has operated sonic drill rigs since 1985. With the implementation of this technique in 1985, North Star was the first U.S. firm to utilize sonic equipment for environmental drilling. This is five to seven years longer than any other existing U.S. company utilizing sonic drill rigs. North Star merged with WTD Environmental Drilling Company in 1995, another Boart Longyear group, to form Boart Longyear's Environmental Drilling Division. With this merger, Boart Longyear's Environmental Drilling Division brings together in one concerted effort Boart Longyear Company's commitment to the environmental drilling industry. We are a blend of innovative technology, long standing family business, aggressive entrepreneur, and a large business corporation. With seven sonic drill rigs and four additional units planned for service later this year, and over 30 auger, rotary and cable tool rigs, Boart Longyear is prepared for your environmental drilling needs.

## The Principle of Sonic Drilling

Sonic Drilling, Rotasonic, Rotosonic, Sonicore, Vibratory or Resonantsonic Drilling, are some of the many names given to a dual cased drilling system that employs the use of high frequency mechanical vibration to take continuous core samples of overburden and most bedrock formations, and to advance casing into the ground.

Any of the names above can be used because they all describe a high frequency vibratory drilling system that is basically the same. The only difference are the rig designs, the operators, and some of the downhole tools and methods of operation that various sonic drillers or companies use. For ease and to be consistent we will refer to this system or method as sonic drilling throughout this article.

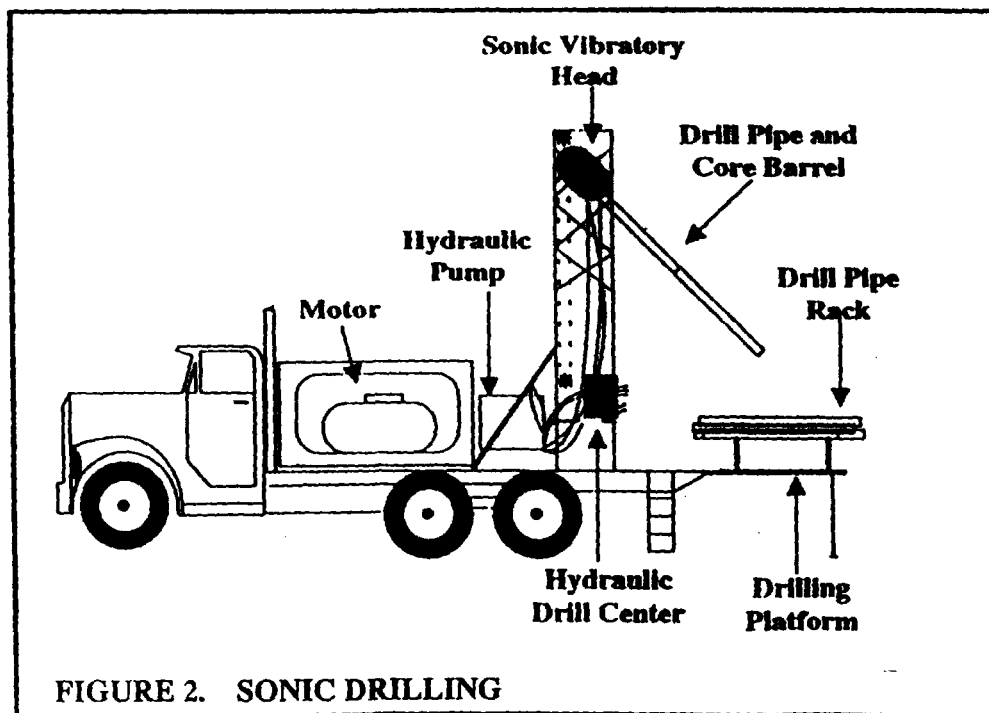
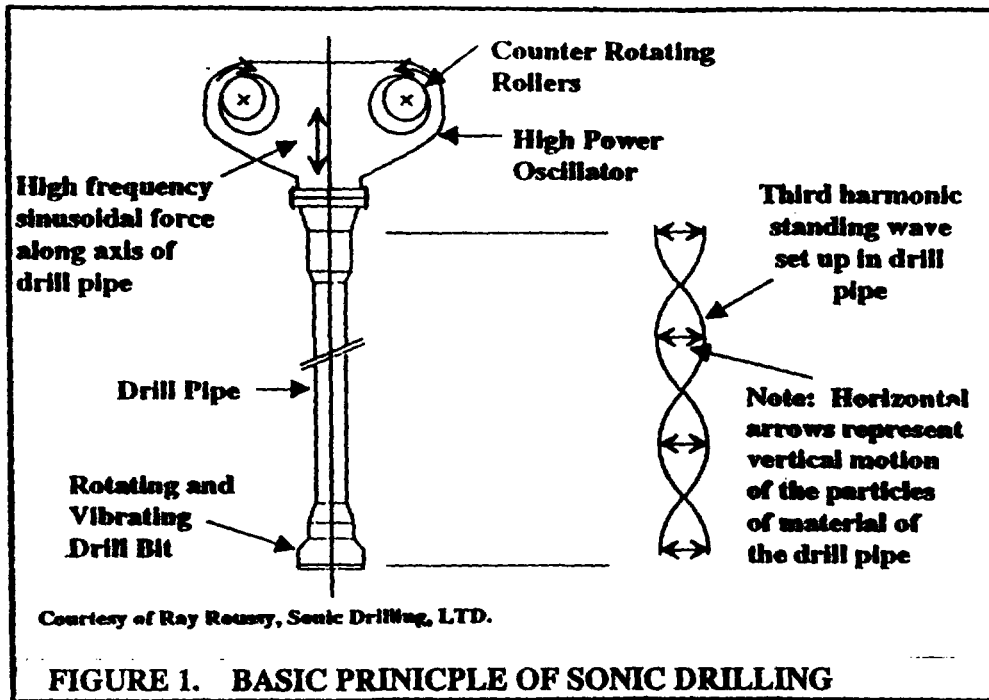
The word sonic appears in most of these names because this drilling technique vibrates the entire drill string at a frequency rate between 50 and 150 hertz or cycles per second. This frequency falls within the lower range of sound vibration that can be detected by the human ear, thus the term sonic has been commonly used to describe this drilling system.

The Rota- or Roto- part of the drilling technique refers to the power applied that slowly rotates the drill string to evenly distribute the energy and the wear at the drill bit face.

A sonic drill rig looks and operates very much like any conventional top-drive rotary or auger rig. The main difference is that a sonic drill rig has a specially designed hydraulically powered drill head or oscillator which generates adjustable high frequency vibrational forces. The sonic head is attached directly to the core barrel, drill pipe or outer casing, sending the high frequency vibrations down through the drill steel to the face of the drill bit.

The oscillator uses two eccentric, counter rotating balance weights or rollers that are timed to direct 100 percent of the vibration at 0 degrees and 180 degrees. There is an air spring system in the oscillator that insulates or separates the vibration from the drill rig itself. This principle is shown in Figure 1.

The vibrational frequency is controlled to suit operating conditions and to achieve optimum drilling rates. When the vibrations coincide with the natural resonate frequency of the steel drill rod or casing a natural phenomenon called resonance occurs, therefore the word resonant. A complete or detailed discussion of resonance is beyond the scope of this article. However, a brief explanation of what resonance does with this system is to allow the rig to transfer the vibrational energy into the top of the drill string, and as the drill string starts to resonate it acts like a flywheel or a spring delivering tremendous amounts of energy directly to the bit face. This plus the fact that the soil particles along the side of the drill string tend to "fluidize" or move away from the drill string allows for very fast penetration rates. In many overburden formations, a sonic drill rig can achieve rates of one foot per second.





## Sonic Bore Hole Advancement

**Process:** The processes which results in borehole advancement are fracturing, shearing and displacement. Drilling through cobbles, boulders and rock is caused by fracturing of the material by the inertial moment of the drill bit. Shearing takes place in dense silts, clay and shales, provided the amplitude of the drill bit is high enough to overcome the elasticity of the formation material. Displacement occurs when unconsolidated formation material is "fluidized" by the vibrating drill string, and it moves away from the drill string. Very few drill cuttings are conveyed to the surface. Most of the formation material enters the core barrel, except for small amounts which are pushed into the borehole wall. As a result, the volume of drill cuttings generated during sonic drilling is much less than hollow-stem auger or cable tool drilling methods.

**Operation:** Optimum penetration rates are obtained when the vibration frequency and down-pressure work in harmony. Experienced drillers have a "feel" when this occurs, and it is monitored by watching the oil pressure gauges in the system. The driller watches the pressure gauges and modifies the frequency of the vibrations being generated, the rotation, or the down pressure for the conditions encountered. Adjustments to the frequency are accomplished with a lever which controls two hydraulic motors that drive the counter-rotating rollers.

Several design features in addition to the use of vibration increases the speed and efficiency of the drilling process. The head, which combines rotation and vibration as previously discussed, is able to pivot 90 degrees. This allows rapid connection of flush-threaded drill pipe by rotating a male-threaded adapter on the head and aligning a length of female-threaded drill pipe directly to the adapter on the head. A fully automated, hydraulic, rotating vise/wrench allows easy breakdown of the drill pipe connections. Once the connection is broken, the head and drill pipe are pivoted to the horizontal position, the rotation is reversed, and the drill pipe is "unscrewed" from the head.

Another feature of the sonic drill rig is a raised drilling platform. The drilling platform is approximately four feet above the ground surface, allowing a safer and cleaner work environment. Drilling operations are conducted without the inconvenience often caused by ground surface conditions (mud, snow, etc.). The drill pipe is stacked on racks on the platform, which increases the speed of adding and removing the drill string. Figure 2 on page 3 is a diagram which displays these features.

## Sonic Drilling System/Method

The sonic drilling system employs simultaneous high-frequency vibrational and low speed rotational motion coupled with down-pressure to advance the cutting edge of a circular drill string. This action produces a uniform borehole while providing relatively continuous, undisturbed core samples of both overburden and most bedrock formations.

This system has many advantages, but the one that seems to be the most unique is the ability to obtain large diameter (four inches to twelve inches) continuous, relatively undisturbed, and very accurate core samples of almost any overburden formation without the use of air, fluid, additives, and with or without rotation. It also can drill and sample through boulders, wood, concrete and other construction debris which with conventional rigs usually causes refusal and necessitates moving and re-drilling. The sonic system can drill and sample most softer bedrock formations such as sandstone, limestone, shale and slate with excellent results. Harder bedrock such as granite can be drilled and sampled though the costs are high due to excessive wear on bits, drill pipe and the drill head. If large amounts of hard bedrock need to be drilled and sampled it is easy to adapt the sonic rig for diamond wire line or air hammer drilling. Most bedrock drilling and sampling requires the addition of water or air or both to remove drill cuttings as with any other rock drilling system.

A sonic drill rig advances a four-inch to twelve inch diameter (nominal) core barrel for sampling and can advance up to a 12 inch diameter outer casing for the construction of standard and telescoped monitoring wells. In drilling, the core barrel is advanced ahead of the outer casing in one to 30 foot increments, depending on the type of material, degree of subsurface contamination and sampling objectives.

The outer casing can be advanced at the same time as the inner drill rods and core barrel, or advanced down over the inner drill rods and core barrel, or after the core barrel has moved ahead to collect the undisturbed core sample and has been pulled out of the borehole. The outer casing can be advanced completely dry in most situations, or it can be advanced with water or air or a drilling fluid with additives depending upon the formations being drilled, the depth and diameter of the borehole, or requirements of the project.

The outer casing prevents cross contamination and formation mixing and allows for very controlled placement of wells or any type of downhole instrumentation. After installing the well screen and riser, the well construction materials, or instrumentation, the outer casing is gently vibrated back out of the borehole. The vibration positively places the well construction material against the borehole wall around the screen and riser. For these reasons and because the sonic does not tend to smear formations, drills dry or with potable water, well development time is usually greatly reduced while well efficiency is enhanced when compared to conventional drilling methods.

The inner drill rods and core barrel are equipped with right hand threads and is rotated in a clockwise direction during sampling. The outer casing is equipped with left hand threads and is rotated in a counter clockwise direction during advancement. This prevents the unscrewing of the inner drill rods and core barrel as the outer casing is advanced.

Core samples can be taken directly from the core barrel attached to the end of the drill string and extruded into a plastic sleeve, metal trough or other suitable receptor. Also, core samples can be collected with clear plastic or stainless steel split liners which are placed inside the core barrel.

The sonic system can be used for almost any type of drilling. At this time, the system is most effective to depths to 400 feet, depending upon conditions. The drill rig utilizing air or wireline tools is capable of drilling much deeper. Today sonic drill rigs are primarily utilized for environmental drilling. Some mineral exploration, construction drilling, angle drilling, water supply wells, and numerous other types of drilling have also been done.

The sonic drilling system results in superior drilling speed through all sediment types while providing for maximum recovery of relatively undisturbed, large diameter cores. Compared to other drilling methods, sonic drilling substantially reduces investigation derived waste and produces uniform boreholes with a minimum of drift ideal for monitoring well construction.

## **Sonic Capabilities and Advantages**

Boart Longyear's sonic capabilities span the different requirements for environmental field activities from preliminary investigations through remediation. Some of these capabilities along with the advantages are listed below.

- Sampling and well installation are faster as compared to drilling with cable tool, hollow stem augers, or rotary methods.
- True continuous sampling, with larger sample volume as compared to split-spoon sampling. Convenient recovery of sufficient soil sample volume where numerous analytes are sampled. Very accurate depiction of the stratigraphy and lithology of any overburden and most bedrock formations are very accurate.
- Sample integrity is increased regardless of lithology. Recovery rates are higher with less sample disturbance than with conventional split spoons.
- The ability to drill through bedrock, cobbles or boulders, sand, hard till, other obstructions without compromising sample volume or integrity, and without redrilling because of refusal.
- Reduction or elimination of sloughing or difficulties with heaving sand conditions.
- Well installations are quick, controlled and positive by elimination of the bridging of the annulus well construction materials during well installation, due to the ability to vibrate the outer casing during removal.
- Reduction of investigation derived waste by an average of 70 to 80 percent as compared to hollow stem augers or the cable tool.
- Less manual labor, decreased trip times, rapid connection/disconnection of drill pipe, and safer working conditions result from the use of hydraulic tongs and wrenches, flush drill rod and casing, and the sonic drill heads ability to pivot 90 degrees from vertical.
- Elimination of direct contact with the sample by field personnel and reduction of the possibility of external contamination of sample by work surfaces because samples are contained within the core barrel with liners or extruded into plastic sleeves at the surface.
- Lined split spoon or thin wall samples can be driven downhole or extracted from the center of the core sample at the surface.
- A sonic rig is easily and quickly converted over for air rotary, fluid rotary, or conventional wire line core drilling, which eliminates the added cost to mobilize additional drill rigs, and added set-up time.
- No water, air or additives are necessary to core sample overburden formations. Water, air or additives are necessary only for core drilling bedrock formations, or can be employed to enhance the speed of advancing the outer casing, and to advance to greater depths in certain formations.
- Effectively drill, case and core sample overburden formations to depths of over 400 feet. The sonic drill can core and drill through virtually any formation or obstruction; there is no such thing as refusal.

- Conduct borings from two inches in diameter through twelve inches in diameter.
- Installation of wells from less than one inch through eight inches in diameter.
- Well abandonment with the sonic is extremely effective where casing has been left in the ground.
- Perched groundwater is easily and accurately located and defined with dry sonic drilling.
- Temporary screens, hydropunches or soil probes can be advanced and set with the sonic drill rig to sample soil, soil gas or in-situ groundwater.
- Groundwater can be collected by push probe well points at substantial depths without generating soil or groundwater as waste.
- Soil samples can be contained within stainless steel split tube liners or Lexan core barrel liners, or extruded into plastic sleeves at the surface.
- Sonic drill rigs core and case angle holes with great efficiency and accuracy from vertical to near horizontal.
- The sonic rig can be positioned in tight locations by working with the service truck back to back, side by side, or the rig can be removed from the truck and placed on the ground and skidded into place or placed on an all terrain vehicle (ATV).
- We have sonic units distributed geographically across the country.
- Staffed full time research and development team and facility with in-house ability, capacity, and experience to modify or adapt drill rigs, downhole tools, and drilling systems as needed for any size or type of project.
- Full environmental insurance coverage is maintained.

We maintain a library of field procedures that can be modified to a client company's site specific requirements and may be included in their work plans. Our experienced staff is available to help with developing new field procedures when needed.

There are few environmental applications we have not experienced since we started using the sonic system in 1985. We are also a full service environmental drilling company and can provide all the other drilling methods (hollow stem auger, cable tool, diamond core drilling, reverse air rotary, etc.) as required or to supplement the sonic capabilities.

As more and more improvements are made and new tools are developed for the sonic drill rigs, the system's advantages will make it even more effective and economical for use in almost any type of shallow drilling application.

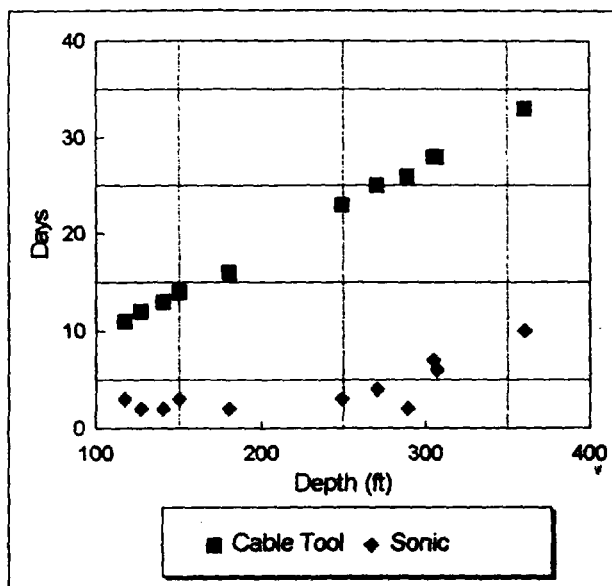
## **Economics of Sonic Utilization**

The cost for sonic drilling when compared to other methods on a straight footage basis are generally higher. However, the net result for a project is generally a significant overall savings considering the greatly reduced investigation derived waste (70% to 80%), analysis and disposal of the waste and the shortened project time with corresponding labor savings. Figures 3 through 5 show drilling time, drilling rates and drilling costs respectively from three different case studies.

The United States Environmental Protection Agency has established guidance for project generated waste entitled Guide to Management of Investigation Derived Waste publication number 93463-02FS, May, 1991. In this document, site managers are asked to strive to minimize investigation derived waste because of the potential hazardous nature of the material and the substantial cost of handling and disposing of the waste. The analytical cost for analyzing waste is approximately \$1000 per sample, depending on the analytes. Some state agencies insist on one sample per drum and will not allow composite sampling. Disposal cost can be as high as \$1800 per drum. There are additional intrinsic costs associated with the storage and handling of investigative derived waste.

**Figure 3. Comparison of Drilling Time (Cable Tool vs Sonic)**

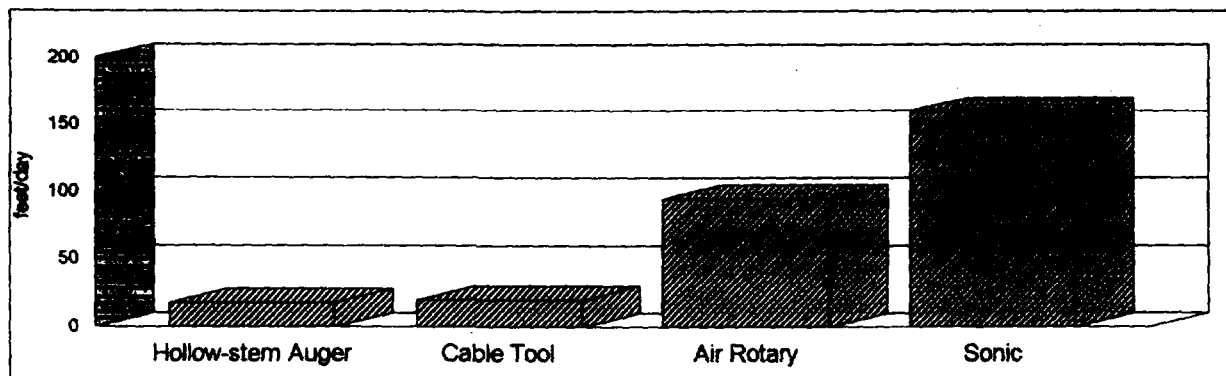
Well	Depth (ft)	Cable Tool	Sonic
1	117	11	3
2	127	12	2
3	140	13	2
4	150	14	3
5	180	16	2
6	249	23	3
7	270	25	4
8	289	26	2
9	305	28	7
10	307	28	6
11	360	33	10
		229	44
		Days	Days



**SOURCE:** Stephan, Robert, IT Corporation, 1994  
 Rotasonic Drilling: An Alternative to Conventional Technology in  
 Environmental Characterization Studies

**Figure 4. Comparison of Drilling Rates and Sample Methods**

Drilling Method	feet/day	Sample Method
Hollow-stem Auger	18	Split-spoon (5 ft)
Cable Tool	20	Bailer
Air Rotary	95	Split-spoon (10 ft)
<b>Sonic</b>	<b>160</b>	<b>Continuous Core</b>



**SOURCE:** Dustman, J., R. Davis and T. Oothoudt, Soil, Bedrock and  
 Groundwater Sampling Using Rotasonic Drilling Techniques, Proc.  
 The Sixth National Outdoor Action Conference on Aquifer Restoration,  
 Ground Water Monitoring, Geophysical Methods, pp. 179-187,  
 National Ground Water Association, Las Vegas, NV 1992

## Standard Test Method for Particle-Size Analysis of Soils<sup>1</sup>

This standard is issued under the fixed designation D 422; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

<sup>1</sup> NOTE—Section 19 was added editorially in September 1990.

### 1. Scope

1.1 This test method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 μm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 μm is determined by a sedimentation process, using a hydrometer to secure the necessary data (Notes 1 and 2).

NOTE 1—Separation may be made on the No. 4 (4.75-mm), No. 40 (425-μm), or No. 200 (75-μm) sieve instead of the No. 10. For whatever sieve used, the size shall be indicated in the report.

NOTE 2—Two types of dispersion devices are provided: (1) a high-speed mechanical stirrer, and (2) air dispersion. Extensive investigations indicate that air-dispersion devices produce a more positive dispersion of plastic soils below the 20-μm size and appreciably less degradation on all sizes when used with sandy soils. Because of the definite advantages favoring air dispersion, its use is recommended. The results from the two types of devices differ in magnitude, depending upon soil type, leading to marked differences in particle size distribution, especially for sizes finer than 20 μm.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants<sup>2</sup>

E 11 Specification for Wire-Cloth Sieves for Testing Purposes<sup>3</sup>

E 100 Specification for ASTM Hydrometers<sup>4</sup>

### 3. Apparatus

3.1 **Balances**—A balance sensitive to 0.01 g for weighing the material passing a No. 10 (2.00-mm) sieve, and a balance sensitive to 0.1 % of the mass of the sample to be weighed for weighing the material retained on a No. 10 sieve.

3.2 **Stirring Apparatus**—Either apparatus A or B may be used.

3.2.1 Apparatus A shall consist of a mechanically oper-

ated stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 10 000 rpm without load. The shaft shall be equipped with a replaceable stirring paddle made of metal, plastic, or hard rubber, as shown in Fig. 1. The shaft shall be of such length that the stirring paddle will operate not less than ¾ in. (19.0 mm) nor more than 1½ in. (38.1 mm) above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 2 shall be provided to hold the sample while it is being dispersed.

3.2.2 Apparatus B shall consist of an air-jet dispersion cup<sup>5</sup> (Note 3) conforming to the general details shown in Fig. 3 (Notes 4 and 5).

NOTE 3—The amount of air required by an air-jet dispersion cup is of the order of 2 ft<sup>3</sup>/min; some small air compressors are not capable of supplying sufficient air to operate a cup.

NOTE 4—Another air-type dispersion device, known as a dispersion tube, developed by Chu and Davidson at Iowa State College, has been shown to give results equivalent to those secured by the air-jet dispersion cups. When it is used, soaking of the sample can be done in the sedimentation cylinder, thus eliminating the need for transferring the slurry. When the air-dispersion tube is used, it shall be so indicated in the report.

NOTE 5—Water may condense in air lines when not in use. This water must be removed, either by using a water trap on the air line, or by blowing the water out of the line before using any of the air for dispersion purposes.

3.3 **Hydrometer**—An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per litre of suspension, and conforming to the requirements for hydrometers 151H or 152H in Specifications E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

3.4 **Sedimentation Cylinder**—A glass cylinder essentially 18 in. (457 mm) in height and 2½ in. (63.5 mm) in diameter, and marked for a volume of 1000 mL. The inside diameter shall be such that the 1000-mL mark is 36 ± 2 cm from the bottom on the inside.

3.5 **Thermometer**—A thermometer accurate to 1°F (0.5°C).

3.6 **Sieves**—A series of sieves, of square-mesh woven-wire cloth, conforming to the requirements of Specification E 11. A full set of sieves includes the following (Note 6):

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

Current edition approved Nov. 21, 1963. Originally published 1935. Replaces D 422 - 62.

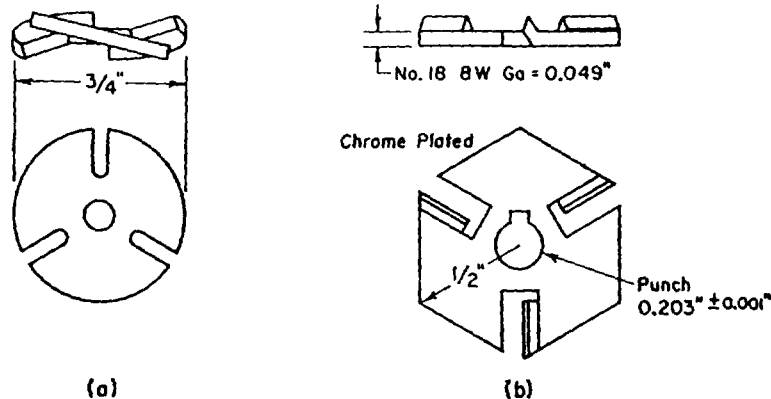
<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

<sup>3</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>4</sup> Annual Book of ASTM Standards, Vol 14.03.

<sup>5</sup> Detailed working drawings for this cup are available at a nominal cost from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103. Order Adjunct No. 12-404220-00.





Metric Equivalents					
in.	0.001	0.049	0.203	1/2	3/4
mm	0.03	1.24	5.16	12.7	19.0

FIG. 1 Detail of Stirring Paddles

3-in. (75-mm)	No. 10 (2.00-mm)
2-in. (50-mm)	No. 20 (850-μm)
1½-in. (37.5-mm)	No. 40 (425-μm)
1-in. (25.0-mm)	No. 60 (250-μm)
¾-in. (19.0-mm)	No. 140 (106-μm)
½-in. (9.5-mm)	No. 200 (75-μm)
No. 4 (4.75-mm)	

NOTE 6—A set of sieves giving uniform spacing of points for the graph, as required in Section 17, may be used if desired. This set consists of the following sieves:

3-in. (75-mm)	No. 16 (1.18-mm)
1½-in. (37.5-mm)	No. 30 (600-μm)
¾-in. (19.0-mm)	No. 50 (300-μm)
½-in. (9.5-mm)	No. 100 (150-μm)
No. 4 (4.75-mm)	No. 200 (75-μm)
No. 8 (2.36-mm)	

**3.7 Water Bath or Constant-Temperature Room**—A water bath or constant-temperature room for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature at or near 68°F (20°C). Such a device is illustrated in Fig. 4. In cases where the work is performed in a room at an automatically controlled constant temperature, the water bath is not necessary.

**3.8 Beaker**—A beaker of 250-mL capacity.

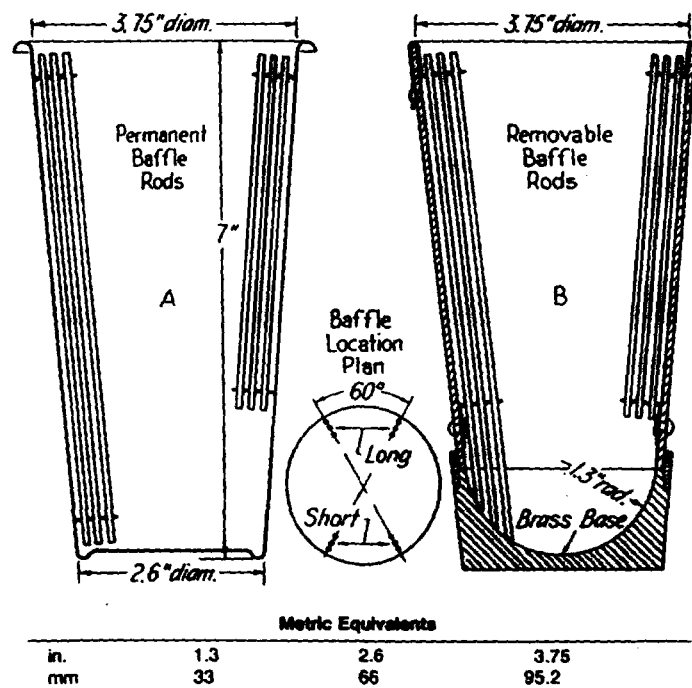
**3.9 Timing Device**—A watch or clock with a second hand.

#### 4. Dispersing Agent

**4.1** A solution of sodium hexametaphosphate (sometimes called sodium metaphosphate) shall be used in distilled or demineralized water, at the rate of 40 g of sodium hexametaphosphate/litre of solution (Note 7).

NOTE 7—Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersive action. Solutions should be prepared frequently (at least once a month) or adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions should have the date of preparation marked on them.

**4.2** All water used shall be either distilled or demineralized water. The water for a hydrometer test shall



Metric Equivalents			
in.	1.3	2.6	3.75
mm	33	66	95.2

FIG. 2 Dispersion Cups of Apparatus

be brought to the temperature that is expected to prevail during the hydrometer test. For example, if the sedimentation cylinder is to be placed in the water bath, the distilled or demineralized water to be used shall be brought to the temperature of the controlled water bath; or, if the sedimentation cylinder is used in a room with controlled temperature, the water for the test shall be at the temperature of the room. The basic temperature for the hydrometer test is 68°F (20°C). Small variations of temperature do not introduce differences that are of practical significance and do not prevent the use of corrections derived as prescribed.

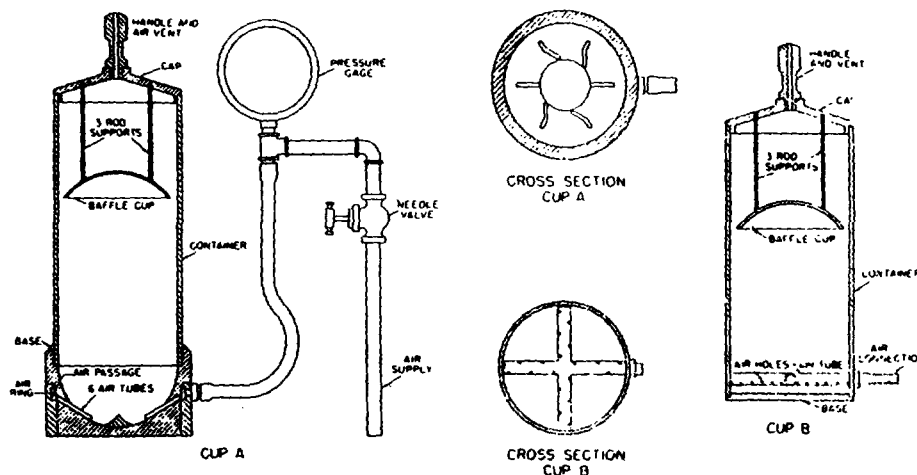


FIG. 3 Air-Jet Dispersion Cups of Apparatus B

## 5. Test Sample

5.1 Prepare the test sample for mechanical analysis as outlined in Practice D 421. During the preparation procedure the sample is divided into two portions. One portion contains only particles retained on the No. 10 (2.00-mm) sieve while the other portion contains only particles passing the No. 10 sieve. The mass of air-dried soil selected for purpose of tests, as prescribed in Practice D 421, shall be sufficient to yield quantities for mechanical analysis as follows:

5.1.1 The size of the portion retained on the No. 10 sieve shall depend on the maximum size of particle, according to the following schedule:

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
3/4 (19.0)	500
1 (25.4)	1000
1 1/2 (38.1)	2000
2 (50.8)	3000
3 (76.2)	4000
	5000

5.1.2 The size of the portion passing the No. 10 sieve shall be approximately 115 g for sandy soils and approximately 65 g for silt and clay soils.

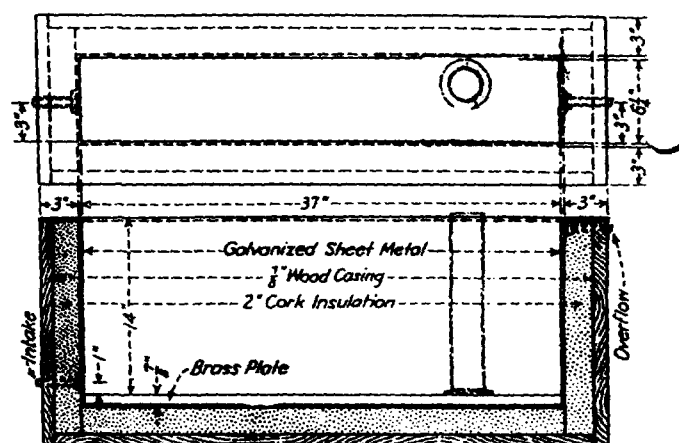
5.2 Provision is made in Section 5 of Practice D 421 for weighing of the air-dry soil selected for purpose of tests, the separation of the soil on the No. 10 sieve by dry-sieving and washing, and the weighing of the washed and dried fraction retained on the No. 10 sieve. From these two masses the percentages retained and passing the No. 10 sieve can be calculated in accordance with 12.1.

NOTE 8—A check on the mass values and the thoroughness of pulverization of the clods may be secured by weighing the portion passing the No. 10 sieve and adding this value to the mass of the washed and oven-dried portion retained on the No. 10 sieve.

### SIEVE ANALYSIS OF PORTION RETAINED ON NO. 10 (2.00-mm) SIEVE

## 6. Procedure

6.1 Separate the portion retained on the No. 10 (2.00-mm) sieve into a series of fractions using the 3-in. (75-mm),



Metric Equivalents						
in.	3/4	1	3	6 1/4	14	37
mm	22.2	25.4	76.2	158.2	356	940

FIG. 4 Insulated Water Bath

2-in. (50-mm), 1 1/2-in. (37.5-mm), 1-in. (25.0-mm), 3/4-in. (19.0-mm), 1/2-in. (12.5-mm), No. 4 (4.75-mm), and No. 10 sieves, or as many as may be needed depending on the sample, or upon the specifications for the material under test.

6.2 Conduct the sieving operation by means of a lateral and vertical motion of the sieve, accompanied by a jarring action in order to keep the sample moving continuously over the surface of the sieve. In no case turn or manipulate fragments in the sample through the sieve by hand. Continue sieving until not more than 1 mass % of the residue on a sieve passes that sieve during 1 min of sieving. When mechanical sieving is used, test the thoroughness of sieving by using the hand method of sieving as described above.

6.3 Determine the mass of each fraction on a balance conforming to the requirements of 3.1. At the end of weighing, the sum of the masses retained on all the sieves used should equal closely the original mass of the quantity sieved.

# HYDROMETER AND SIEVE ANALYSIS OF PORTION PASSING THE NO. 10 (2.00-mm) SIEVE

## 7. Determination of Composite Correction for Hydrometer Reading

7.1 Equations for percentages of soil remaining in suspension, as given in 14.3, are based on the use of distilled or demineralized water. A dispersing agent is used in the water, however, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

7.1.1 Both soil hydrometers are calibrated at 68°F (20°C), and variations in temperature from this standard temperature produce inaccuracies in the actual hydrometer readings. The amount of the inaccuracy increases as the variation from the standard temperature increases.

7.1.2 Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

7.1.3 The net amount of the corrections for the three items enumerated is designated as the composite correction, and may be determined experimentally.

7.2 For convenience, a graph or table of composite corrections for a series of 1° temperature differences for the range of expected test temperatures may be prepared and used as needed. Measurement of the composite corrections may be made at two temperatures spanning the range of expected test temperatures, and corrections for the intermediate temperatures calculated assuming a straight-line relationship between the two observed values.

7.3 Prepare 1000 mL of liquid composed of distilled or demineralized water and dispersing agent in the same proportion as will prevail in the sedimentation (hydrometer) test. Place the liquid in a sedimentation cylinder and the cylinder in the constant-temperature water bath, set for one of the two temperatures to be used. When the temperature of the liquid becomes constant, insert the hydrometer, and, after a short interval to permit the hydrometer to come to the temperature of the liquid, read the hydrometer at the top of the meniscus formed on the stem. For hydrometer 151H the composite correction is the difference between this reading and one; for hydrometer 152H it is the difference between the reading and zero. Bring the liquid and the hydrometer to the other temperature to be used, and secure the composite correction as before.

## 8. Hygroscopic Moisture

8.1 When the sample is weighed for the hydrometer test, weigh out an auxiliary portion of from 10 to 15 g in a small metal or glass container, dry the sample to a constant mass in an oven at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ), and weigh again. Record the masses.

## 9. Dispersion of Soil Sample

9.1 When the soil is mostly of the clay and silt sizes, weigh out a sample of air-dry soil of approximately 50 g. When the soil is mostly sand the sample should be approximately 100 g.

9.2 Place the sample in the 250-mL beaker and cover with 125 mL of sodium hexametaphosphate solution (40 g/L). Stir until the soil is thoroughly wetted. Allow to soak for at least 16 h.

9.3 At the end of the soaking period, disperse the sample further, using either stirring apparatus A or B. If stirring apparatus A is used, transfer the soil - water slurry from the beaker into the special dispersion cup shown in Fig. 2, washing any residue from the beaker into the cup with distilled or demineralized water (Note 9). Add distilled or demineralized water, if necessary, so that the cup is more than half full. Stir for a period of 1 min.

NOTE 9—A large size syringe is a convenient device for handling the water in the washing operation. Other devices include the wash-water bottle and a hose with nozzle connected to a pressurized distilled water tank.

9.4 If stirring apparatus B (Fig. 3) is used, remove the cover cap and connect the cup to a compressed air supply by means of a rubber hose. A air gage must be on the line between the cup and the control valve. Open the control valve so that the gage indicates 1 psi (7 kPa) pressure (Note 10). Transfer the soil - water slurry from the beaker to the air-jet dispersion cup by washing with distilled or demineralized water. Add distilled or demineralized water, if necessary, so that the total volume in the cup is 250 mL, but no more.

NOTE 10—The initial air pressure of 1 psi is required to prevent the soil - water mixture from entering the air-jet chamber when the mixture is transferred to the dispersion cup.

9.5 Place the cover cap on the cup and open the air control valve until the gage pressure is 20 psi (140 kPa). Disperse the soil according to the following schedule:

Plasticity Index	Dispersion Period, min
Under 5	5
6 to 20	10
Over 20	15

Soils containing large percentages of mica need be dispersed for only 1 min. After the dispersion period, reduce the gage pressure to 1 psi preparatory to transfer of soil - water slurry to the sedimentation cylinder.

## 10. Hydrometer Test

10.1 Immediately after dispersion, transfer the soil - water slurry to the glass sedimentation cylinder, and add distilled or demineralized water until the total volume is 1000 mL.

10.2 Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min to complete the agitation of the slurry (Note 11). At the end of 1 min set the cylinder in a convenient location and take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

NOTE 11—The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns.

Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

10.3 When it is desired to take a hydrometer reading, carefully insert the hydrometer about 20 to 25 s before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning motion in a graduate of clean distilled or demineralized water.

NOTE 12—It is important to remove the hydrometer immediately after each reading. Readings shall be taken at the top of the meniscus formed by the suspension around the stem, since it is not possible to secure readings at the bottom of the meniscus.

10.4 After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

## 11. Sieve Analysis

11.1 After taking the final hydrometer reading, transfer the suspension to a No. 200 (75- $\mu$ m) sieve and wash with tap water until the wash water is clear. Transfer the material on the No. 200 sieve to a suitable container, dry in an oven at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ) and make a sieve analysis of the portion retained, using as many sieves as desired, or required for the material, or upon the specification of the material under test.

## CALCULATIONS AND REPORT

### 12. Sieve Analysis Values for the Portion Coarser than the No. 10 (2.00-mm) Sieve

12.1 Calculate the percentage passing the No. 10 sieve by dividing the mass passing the No. 10 sieve by the mass of soil originally split on the No. 10 sieve, and multiplying the result by 100. To obtain the mass passing the No. 10 sieve, subtract the mass retained on the No. 10 sieve from the original mass.

12.2 To secure the total mass of soil passing the No. 4 (4.75-mm) sieve, add to the mass of the material passing the No. 10 sieve the mass of the fraction passing the No. 4 sieve and retained on the No. 10 sieve. To secure the total mass of soil passing the  $\frac{1}{2}$ -in. (9.5-mm) sieve, add to the total mass of soil passing the No. 4 sieve, the mass of the fraction passing the  $\frac{1}{2}$ -in. sieve and retained on the No. 4 sieve. For the remaining sieves, continue the calculations in the same manner.

12.3 To determine the total percentage passing for each sieve, divide the total mass passing (see 12.2) by the total mass of sample and multiply the result by 100.

### 13. Hygroscopic Moisture Correction Factor

13.1 The hygroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

### 14. Percentages of Soil in Suspension

14.1 Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

14.2 Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the No. 10

TABLE 1 Values of Correction Factor,  $\alpha$ , for Different Specific Gravities of Soil Particles<sup>A</sup>

Specific Gravity	Correction Factor <sup>A</sup>
2.95	0.94
2.90	0.95
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.03
2.45	1.05

<sup>A</sup> For use in equation for percentage of soil remaining in suspension when using Hydrometer 152H.

(2.00-mm) sieve, and multiplying the result by 100. This value is the weight  $W$  in the equation for percentage remaining in suspension.

14.3 The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows (Note 13): For hydrometer 151H:

$$P = [(100\,000/W) \times G/(G - G_1)](R - G_1)$$

NOTE 13—The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

$$P = (Ra/W) \times 100$$

where:

$\alpha$  = correction factor to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1),

$P$  = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension,

$R$  = hydrometer reading with composite correction applied (Section 7),

$W$  = oven-dry mass of soil in a total test sample represented by mass of soil dispersed (see 14.2), g,

$G$  = specific gravity of the soil particles, and

$G_1$  = specific gravity of the liquid in which soil particles are suspended. Use numerical value of one in both instances in the equation. In the first instance any possible variation produces no significant effect, and in the second instance, the composite correction for  $R$  is based on a value of one for  $G_1$ .

### 15. Diameter of Soil Particles

15.1 The diameter of a particle corresponding to the percentage indicated by a given hydrometer reading shall be calculated according to Stokes' law (Note 14), on the basis that a particle of this diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer is measuring the density of the suspension. According to Stokes' law:

$$D = \sqrt{[30n/980(G - G_1)] \times L/T}$$

where:

$D$  = diameter of particle, mm,

- $n$  = coefficient of viscosity of the suspending medium (in this case water) in poises (varies with changes in temperature of the suspending medium).
- $L$  = distance from the surface of the suspension to the level at which the density of the suspension is being measured, cm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth (Table 2)),
- $T$  = interval of time from beginning of sedimentation to the taking of the reading, min,
- $G$  = specific gravity of soil particles, and
- $G_1$  = specific gravity (relative density) of suspending medium (value may be used as 1.000 for all practical purposes).

NOTE 14—Since Stokes' law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

15.2 For convenience in calculations the above equation may be written as follows:

$$D = K\sqrt{L/T}$$

where:

$K$  = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of  $K$  for a range of temperatures and specific gravities are given in Table 3. The value of  $K$  does not change for a series of readings constituting a test, while values of  $L$  and  $T$  do vary.

15.3 Values of  $D$  may be computed with sufficient accuracy, using an ordinary 10-in. slide rule.

NOTE 15—The value of  $L$  is divided by  $T$  using the  $A$ - and  $B$ -scales, the square root being indicated on the  $D$ -scale. Without ascertaining the value of the square root it may be multiplied by  $K$ , using either the  $C$ - or  $CI$ -scale.

## 16. Sieve Analysis Values for Portion Finer than No. 10 (2.00-mm) Sieve

16.1 Calculation of percentages passing the various sieves used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the No. 10 sieve had it not been removed. This mass is equal to the total percentage retained on the No. 10 sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in 14.2), and the result divided by 100.

16.2 Calculate next the total mass passing the No. 200 sieve. Add together the fractional masses retained on all the sieves, including the No. 10 sieve, and subtract this sum from the mass of the total sample (as calculated in 14.2).

16.3 Calculate next the total masses passing each of the other sieves, in a manner similar to that given in 12.2.

16.4 Calculate last the total percentages passing by dividing the total mass passing (as calculated in 16.3) by the total mass of sample (as calculated in 14.2), and multiply the result by 100.

## 17. Graph

17.1 When the hydrometer analysis is performed, a graph

TABLE 2 Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes<sup>a</sup>

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5		
1.006	14.7	6	15.3	36	10.4
1.007	14.4	7	15.2	37	10.2
1.008	14.2	8	15.0	38	10.1
1.009	13.9	9	14.8	39	9.9
1.010	13.7	10	14.7	40	9.7
1.011	13.4	11	14.5	41	9.6
1.012	13.1	12	14.3	42	9.4
1.013	12.9	13	14.2	43	9.2
1.014	12.6	14	14.0	44	9.1
1.015	12.3	15	13.8	45	8.9
1.016	12.1	16	13.7	46	8.8
1.017	11.8	17	13.5	47	8.6
1.018	11.5	18	13.3	48	8.4
1.019	11.3	19	13.2	49	8.3
1.020	11.0	20	13.0	50	8.1
1.021	10.7	21	12.9	51	7.9
1.022	10.5	22	12.7	52	7.8
1.023	10.2	23	12.5	53	7.6
1.024	10.0	24	12.4	54	7.4
1.025	9.7	25	12.2	55	7.3
1.026	9.4	26	12.0	56	7.1
1.027	9.2	27	11.9	57	7.0
1.028	8.9	28	11.7	58	6.8
1.029	8.6	29	11.5	59	6.6
1.030	8.4	30	11.4	60	6.5
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				

<sup>a</sup> Values of effective depth are calculated from the equation:

$$L = L_1 + \frac{1}{2} [L_2 - (V_b/A)]$$

where:

- $L$  = effective depth, cm,  
 $L_1$  = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, cm,  
 $L_2$  = overall length of the hydrometer bulb, cm,  
 $V_b$  = volume of hydrometer bulb, cm<sup>3</sup>, and  
 $A$  = cross-sectional area of sedimentation cylinder, cm<sup>2</sup>

Values used in calculating the values in Table 2 are as follows:

For both hydrometers, 151H and 152H:

- $L_2$  = 14.0 cm  
 $V_b$  = 67.0 cm<sup>3</sup>  
 $A$  = 27.8 cm<sup>2</sup>

For hydrometer 151H:

- $L_1$  = 10.5 cm for a reading of 1.000  
 = 2.3 cm for a reading of 1.031

For hydrometer 152H:

- $L_1$  = 10.5 cm for a reading of 0 g/litre  
 = 2.3 cm for a reading of 50 g/litre

of the test results shall be made, plotting the diameters of the particles on a logarithmic scale as the abscissa and the percentages smaller than the corresponding diameters to an

TABLE 3 Values of K for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature, °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.1323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

arithmetic scale as the ordinate. When the hydrometer analysis is not made on a portion of the soil, the preparation of the graph is optional, since values may be secured directly from tabulated data.

## 18. Report

18.1 The report shall include the following:

18.1.1 Maximum size of particles,

18.1.2 Percentage passing (or retained on) each sieve, which may be tabulated or presented by plotting on a graph (Note 16),

18.1.3 Description of sand and gravel particles:

18.1.3.1 Shape—rounded or angular,

18.1.3.2 Hardness—hard and durable, soft, or weathered and friable,

18.1.4 Specific gravity, if unusually high or low,

18.1.5 Any difficulty in dispersing the fraction passing the No. 10 (2.00-mm) sieve, indicating any change in type and amount of dispersing agent, and

18.1.6 The dispersion device used and the length of the dispersion period.

NOTE 16—This tabulation of graph represents the gradation of the sample tested. If particles larger than those contained in the sample were removed before testing, the report shall so state giving the amount and maximum size.

18.2 For materials tested for compliance with definite specifications, the fractions called for in such specifications shall be reported. The fractions smaller than the No. 10 sieve shall be read from the graph.

18.3 For materials for which compliance with definite specifications is not indicated and when the soil is composed almost entirely of particles passing the No. 4 (4.75-mm) sieve, the results read from the graph may be reported as follows:

- (1) Gravel, passing 3-in. and retained on No. 4 sieve .....
- (2) Sand, passing No. 4 sieve and retained on No. 200 sieve .....
- (a) Coarse sand, passing No. 4 sieve and retained on No. 10 sieve .....
- (b) Medium sand, passing No. 10 sieve and retained on No. 40 sieve .....
- (c) Fine sand, passing No. 40 sieve and retained on No. 200 sieve .....
- (3) Silt size, 0.074 to 0.005 mm .....
- (4) Clay size, smaller than 0.005 mm .....
- Colloids, smaller than 0.001 mm .....

18.4 For materials for which compliance with definite specifications is not indicated and when the soil contains material retained on the No. 4 sieve sufficient to require a sieve analysis on that portion, the results may be reported as follows (Note 17):

### SIEVE ANALYSIS

Sieve Size	Percentage Passing
3-in.	.....
2-in.	.....
1½-in.	.....
1-in.	.....
¾-in.	.....
½-in.	.....
No. 4 (4.75-mm)	.....
No. 10 (2.00-mm)	.....
No. 40 (425-µm)	.....
No. 200 (75-µm)	.....

### HYDROMETER ANALYSIS

0.074 mm	.....
0.005 mm	.....
0.001 mm	.....

NOTE 17—No. 8 (2.36-mm) and No. 50 (300-µm) sieves may be substituted for No. 10 and No. 40 sieves.

## 19. Keywords

19.1 grain-size; hydrometer analysis; hygroscopic moisture; particle-size; sieve analysis

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## MONTGOMERY WATSON

### FIELD SAMPLING AND TESTING SOPs AND TGDs

<b>Section</b>	Subsurface Exploration and Sampling	<b>Section Number</b>	206A	<b>Date of Issue</b>	April 1993	<b>Reviewed By</b>	G. Prior
<b>Subject</b>	Groundwater Level Monitoring using Two-Channel Hermit Data Logger	<b>Page of</b>	1 10	<b>Date Revised</b>	\	<b>Authorized By</b>	\

**Subject:** Operating the Two-Channel Hermit Data Logger Model SE1000B with Pressure Transducer

**Scope:** This method is applicable to recording water level changes in wells. Pre-field operation checks for functionality and drift are included.

**Method:** Pressure Transducer with electrical data sampling and storage.

**Reference:** Operator's Manuals for Hermit Datalogger and PXD-260 Pressure Transducer

#### I. Application

##### A. Monitoring changes in static water levels

B. Monitoring wells MW7, MW9 and piezometer P8 will be instrumented with pressure transducers connected to Hermit data loggers for the purpose of collecting groundwater levels. Groundwater levels will be recorded at 30-minute intervals for the duration of Vertical Profiling activities and subsequent monitoring well installation activities (duration of field activities estimated at 30 days).

#### II. Hermit Data Logger and Pressure Transducer Operation Check

A. Perform these three tests in a controlled temperature setting at least 48 hours before field work.

##### B. Hermit Data Logger

1. Connect pressure transducer to hermit with pressure transducer on desk.
2. Follow III, C through E #14 (Operation for Groundwater Level Monitoring)
3. Select 'FUNC', then press 'ENTER', displays '8025'
4. Press 'STOP/NEXT'; displays idle mode

## MONTGOMERY WATSON

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### FIELD SAMPLING AND TESTING SOPs AND TGDs

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<b>Subject</b>	Groundwater Level Monitoring using Two-Channel Hermit Data Logger	<b>Page of</b>	2 10	<b>Date Revised</b>	\	<b>Authorized By</b>	\

5. Hold 'ENTER' and press 'XD'; displays 'SCALE'
6. Press 'ENTER'; displays a number
7. Use 'STOP/NEXT' and scan to display 16.00, press 'ENTER'
8. Scan down to 'OFFS'; press 'ENTER'; displays a number
9. Use 'STOP/NEXT' and scan to display 4.00; press 'ENTER'
10. Press 'STOP/NEXT'; displays idle mode
11. Press 'XD'; displays a number which should be between 3.5 and 4.5
12. Hermit data logger cannot be used if the XD value is not between 3.5 and 4.5

#### C. Pressure Transducer Functionality

1. Select a container 2 1/2 to 4 ft tall with an inside diameter of 1 to 2 ft
2. Place >2 ft of room temperature (not hot, not cold) water into the container
3. Attach a tape measure to the transducer piece with zero at the transducer sensor
4. Immerse the transducer to the 2.00 ft mark
5. Follow III, B through F #1 (Operation for Groundwater Level Monitoring)
6. Use 'STOP/NEXT' and scan to display '00.00'; press 'ENTER'
7. Follow III, F #3 to F #7 (Operation for Groundwater Level Monitoring)
8. Press 'STOP/NEXT' to return to idle mode
9. Press 'XD' and record the value



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10. Repeat for 1.50', 1.00', and 0.50'

11. 'Do not use the pressure transducer if 'XD' values deviate from the actual value by more than  $\pm 0.11\%$  of full scale (see Attachment 1)

#### D. Pressure Transducer Drift

1. Place data logger, pressure transducer and a 5 gal bucket of room temperature water in a secure place
2. With hermit connected to the pressure transducer and with the transducer immersed in water and secured, press 'START' then 'ENTER' to begin an overnight test
3. Place a warning sign 'Test in Progress - Don't Mess With'
4. Let the test run for >10 hours
5. Stop test and down load data
6. Do not use the pressure transducer if values deviate by more than  $\pm 0.11\%$  of full scale (see Attachment 1)

### III. Operation for Groundwater Level Monitoring

- A. Place pressure transducer into the well
- B. Hook up pressure transducer to hermit
- C. 'WAKE UP' hermit; displays 8:8:8.8.8 during internal checks; may briefly show 'LO BAT' but don't worry. IF 'LOBAT' continues to be displayed, approximately ten hours of 'wake' time remain. External power may be used to supplement battery power until the battery can be replaced.
- D. Idle mode; falls back asleep after 30 sec. of inactivity

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#### E. Defining a test

1. Hold 'ENTER' and press 'DATA'
2. Display reads SEL \_\_\_\_ (0 to 9)
3. Press 'ENTER'; display reads SEL (blinking number). Tests are numbered from 0 to 9. When defining a test, data for all successive test numbers are erased (e.g., if test #0 is selected the entire memory is cleared). Define the first test as #0, the next test and so on up to #9.
4. Press 'SCAN' to scan down to 0, press 'ENTER'
5. Display reads '8025', then returns to SEL 0
6. Scan down to 'RATE', press 'ENTER'
7. Scan up or down for log mode or linear mode
8. Select linear mode and press 'ENTER'
9. Set to 00:30 (readings @ 30-minute intervals), press 'ENTER' displays 8025 and returns to 'RATE'
10. Scan down to INP, press 'ENTER'
11. Scan up or down for input 1 or 2 (as appropriate)
12. Select input 1, press 'ENTER', displays 8025
13. Scan down to 'TYPE', then press 'ENTER'
14. Scan up or down for 'DUAL', 'FUNC', or 'LEVEL'
15. Select 'LEVEL', then press 'ENTER', displays 8025

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#### F. Set transducer parameters

1. Hold `ENTER` and press `XD`: displays REF; press `ENTER`
2. Press `STOP/NEXT` and scan to set depth to water; confirm correct depth to water is displayed; press `ENTER`
3. Press `STOP/NEXT` then scan down to display `SCALE`. The scale factor is unique to each pressure transducer and is located on a decal on the side of the pressure transducer reel; use `STOP/NEXT` and scan to set the scale factor; confirm correct scale factor is displayed; press `ENTER`
4. Scan down to `OFFS`; press `ENTER`
5. Press `STOP/NEXT` and scan to set the proper offset number. The offset number is unique to each pressure transducer. It is also located on a decal on the side of the pressure transducer reel; confirm correct offset is displayed, enter zero if offset is negative; press `ENTER`
6. Scan down to `DSP`, press `ENTER`
7. Scan down to display choices: EN:TOC, EN:SUR, SI:TOC, or SI:SUR; select EN:TOC (English, top of casing) and press `ENTER`

#### G. Starting a test

1. Must display idle mode
2. Immediate start
  - a. Must display idle mode.
  - b. Press `START`; displays test number, then displays `START`
  - c. Press `ENTER`; hermit begins recording data immediately

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3. Viewing data while test is running
  - a. Must wait until ten minutes after test has started
  - b. Wake up hermit; displays 'RUN' mode
  - c. Press 'DATA'; displays 'DSP (test number)'
  - d. Use 'SCAN' to display desired test number, then press 'ENTER'
  - e. displays time (minutes) then reading at that time; scan down to the next time increment and reading
  - f. Hold 'ENTER' and press 'SCAN DOWN' to fast forward ten display readings; displays time (minutes) then reading at that time

#### H. Stopping a test

1. Hold 'ENTER' and press 'STOP/NEXT'; displays 'STOP'
2. Press 'ENTER' to confirm stop, or press 'STOP/NEXT' to cancel

### IV. DOWNLOADING DATA

#### A. Field printer operation

1. Connect RS232 port to the SE1004B printer; be certain the printer is turned off
2. Connect printer to external power source
3. Wake up hermit; idle mode or run mode
4. Hit 'ENTER' and 'START' simultaneously; displays 'UNIT'; caution: if you hit 'START', then 'ENTER' this will erase data

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5. Scan down to `PORT`; press `ENTER`; displays `BAUD`
6. Press `ENTER`; displays `300`, `600`, `1200` or `2400`; scan to `1200`, press `ENTER`; displays `BAUD`
7. Turn printer switch to `ON`; printer will type `READY`
8. Press `DATA`; displays `OUT (Number)`
9. Scan to display the test number to be printed
10. Press `ENTER`; printer will print current date and time, unit number, test number, reference level, scale factor, offset, test date and time, and test readings
11. To stop printing (to abort), turn printer off

#### B. IBM compatible computer

1. Connect the RS232 port to port 1 of the computer
2. Press `ENTER` and `START` simultaneously; displays `UNIT`; caution: if you press `START` then `ENTER` data will be erased
3. Scan down to `PORT`; press `ENTER`; displays `BAUD`
4. Press `ENTER`; displays `300`, `600`, `1200`, or `2400`; scan to `2400`, press `ENTER`; displays `BAUD`
5. Scan down to `CHAR`; press `ENTER`; scan to `8:no`, press `ENTER`
6. Scan down to `EOL`, press `ENTER` scan to `Cr\_LF`, press `ENTER`
7. Run the communications software on the computer by typing `DATATRAN`
8. Direct input to a disk drive and file name (i.e., C:acsmw9.dat)

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9. Wake up Hermit; press `DATA'; displays' OUT (test number)
10. Scan to the highest test number; press `ENTER'
11. Hit 'F1' on keyboard to initiate data transfer from data logger to designated disk drive

#### C. Manually using Hermit Data Logger Data Collection Form

1. Wake up hermit; displays either idle mode or run mode
2. Press `DATA'; displays `DSP.(test number)'
3. Scan up or down to desired test number
4. Press `ENTER'; displays time (minutes), then displays reading
5. Record reading onto data collection form opposite appropriate time
6. Scan down to the next time increment reading

### V. SHIPPING AND TRANSPORT

#### A. Paperwork: Federal Express Restricted Articles Airbill for overnight shipping

1. Check: Dangerous goods as per attached shipper's declaration
2. Check: Cargo aircraft only
3. Shipping weight: 70 lbs
4. Check: IATA/ICAO
5. Proper shipping name: Lithium Batteries Contained in Equipment

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6. Class or division: 9
7. UN or ID No.: UN3091
8. Subsidiary risk: leave blank
9. Quantity and type of packaging: Fiberboard box; X55 grams (11 grams per cell)
10. Packing inst: 912, II
11. Authorization: DOT-E-7052
12. Additional information: Cargo Aircraft Only/emergency response #800-424-9300
13. Delete: passenger aircraft
14. Delete: radioactive
15. Emergency telephone number: 1-800-424-9300
16. Name and title of shipper: your name and title
17. Sign your name

**B. Packaging: Ship in hermit shipping container**

1. Labels: Cargo Aircraft Only (2)  
Flammable Solid (2)  
This Side Up (2)  
UN3091 (2)  
Lithium Batteries in Equipment (2)  
Shipped per DOT-E-7052
2. Attach a copy of DOT-E-7052 to the outside of the container

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		10 10	\	\

C. Do not take Hermit onto airplane as carryon luggage, nor as checked baggage

GFP/cas  
J:\4077\0030\WORK\_PL\HERMIT.WPD





5214 S. EAST STREET  
INDIANAPOLIS, IN 46227  
PHONE • 317-787-9167

GEOLOGIC/ENVIRONMENTAL CONSULTANTS

September 20, 1994

Mr. Patrick Carroll  
Office of Solid Waste  
Indiana Department of Environmental Management  
100 North Senate Avenue  
Indianapolis, Indiana 46204

RE: Statistical Analysis of Groundwater Monitoring  
Griffith Landfill  
REB Project No. 1408

Dear Mr. Carroll:

R.E. Blatter & Associates, Inc. (REB) respectfully submits this statistical analysis report for groundwater monitoring well samples collected at the Griffith Landfill. The most recent sampling event was conducted on July 27, 1994.

If you have any questions or require additional information, please contact our office at (317) 787-9167.

Respectfully,  
R.E. BLATTERT & ASSOCIATES, INC.

A handwritten signature in cursive script, reading "Elizabeth A. White".

Elizabeth A. White  
Project Manager

EAW/am  
Enclosures



5214 S. EAST STREET  
INDIANAPOLIS, IN 46227  
PHONE • 317-787-9167

GEOLOGIC ENVIRONMENTAL CONSULTANTS

### STATISTICAL ANALYSIS SUMMARY

Project: Griffith Landfill Phase I & II Groundwater Sampling  
Period: Sampling Event conducted on 7/27/94  
Submitted to: Mr. Patrick Carroll; IDEM Solid Waste Branch

Statistical Method: Student's t Method

Summary: Confidence level, 95%, One Tail Test  
Upper and lower limits were calculated from background wells  
Monitoring Well MW-1D and MW-1S.

Conclusions: There were no statistically significant increases over background, per 329 IAC 2-16.

The secondary maximum contaminant level (SMCL) for manganese, 0.05 milligrams per liter (mg/L), was exceeded in upgradient Monitoring Well MW-1S, at a concentration of 0.452 mg/L, as shown in Table 10.

The secondary maximum contaminant level (SMCL) for total dissolved solids, 500 mg/L, was exceeded in upgradient Monitoring Well MW-1S, at a concentration of 1,073 mg/L, as shown in Table 10.

The secondary maximum contaminant level (SMCL) for iron, 0.03 mg/L, was exceeded in upgradient Monitoring Well MW-1S, at a concentration of 1.5 mg/L, as shown in Table 10.

The secondary maximum contaminant level (SMCL) for chloride, 250 mg/L, was exceeded in downgradient Monitoring Well MW-4S, at a concentration of 877 mg/L, as shown in Table 13.

If you have questions please contact me at (317) 787-9167.

Sincerely,  
R. E. BLATTERT & ASSOCIATES, INC.

*Elizabeth A. White*  
Elizabeth A. White  
Project Manager

EAW/am  
Enclosures

cc: Ron Cooper, Department of Public Works  
Griffith, Indiana

#	PARAMETER	MCL	SMCL	SUM	AVE	VARIANCE	STD DEV	SAMPLING EVENTS MW-4D		
								8/28/03	1/31/04	7/27/04
1										
2										
3										
4	BENZENE	0.005		0	0	0	0	0	0	0
5										
6										
7										
8	METHYL ETHYL KETONE (MEK)			0	0	0	0	0	0	0
9										
10										
11										
12										
13										
14										
15										
16										
17										
18	1,1-DICHLOROETHANE			0	0	0	0	0	0	0
19										
20	1,2-DICHLOROETHENE (TOTAL)			0	0	0	0	0	0	0
21										
22										
23	ETHYLBENZENE	0.7	0.03	0	0	0	0	0	0	0
24										
25										
26										
27	METHYLENE CHLORIDE			0	0	0	0	0	0	0
28										
29										
30	TOLUENE	0.2		0	0	0	0	0	0	0
31										
32										
33										
34										
35										
36										
37										
38										
39	FIELD pH		6.5-8.5	22.65	7.818867	0.011622	0.104987	7.47	7.71	7.67
40	FIELD CONDUCTIVITY			2437	479	206.2802	14.35661	967	1000	998
41	COO			62	20.66667	28.63889	5.35148	28	17	17
42	PHENOLICS (TOTAL)			0	0	0	0	0	0	0
43										
44										
45	CHLORIDE		250	468	188	96.60887	9.83311	150	170	148
46	AMMONIA			0.9	0.3	0.048889	0.219025	0.4	0.5	0.3
47										
48										
49										
50										
51										
52										
53										
54										
55										
56										
57										
58	SODIUM			132.44	44.14087	999.2217	31.61047	57	0.84	74.8
59										
60	BORON			1.361	0.453667	0.06746	0.259708	0.78	0.37	0.211
61										
62										
63										
64										

TABLE 4: DOWN-GRADIENT MW-4D